The JOURNAL
OF THE
FRANKLIN INSTITUTE
OF THE STATE OF PENNSYLVANIA
DEVOTED TO SCIENCE AND THE MECHANIC ARTS

VOL. CLXX JULY, 1910 No. 1

MAGNETIC HYSTERESIS.

BY
MORTON G. LLOYD,
Associate Physicist, Bureau of Standards, Washington, D. C.

(*Presented at a Stated Meeting of the Electrical Section, held Thursday, April* 28, 1910.)

[Essential to the correct design of electrical machinery is a complete knowledge of the physical magnetic and electrical properties of the elements which enter most largely into its composition, namely, steel or iron, copper, and insulating material. In the following paper the Author treats exhaustively of the latest methods of measuring magnetic quality in general and in particular the losses which occur in iron and iron alloys when placed in alternating and rotary magnetic fields. The results clearly show the great improvement made in recent years in the quality of the magnetic material used in such enormous quantities by the manufacturer of electrical apparatus of to-day. They also show along what lines research may be made with the probable result of still greater improvement.]

THE name 'hysteresis' is applied to the tendency of magnetic materials to persist in any magnetic state which already exists. It is due to this property that we have such a thing as a permanent magnet. If a specimen is exposed to a magnetizing field which gradually increases in value and then gradually decreases, the value of the resultant magnetization corresponding to a particular magnetizing field is different for increasing and for decreasing values. The magnetizing field may be reduced to zero, but some residual magnetization remains, and it requires a negative magnetizing field to reduce the magnetization to zero.

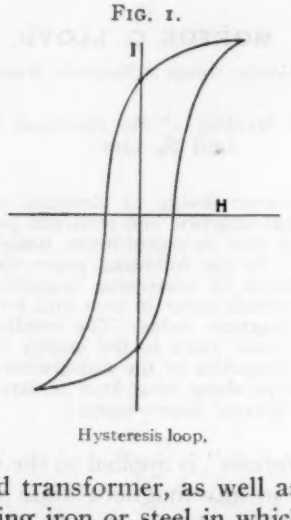
[NOTE.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the Journal.]

227007

In short, the magnetization appears to lag behind the changes in the magnetizing field, and it was for this reason that Prof. Ewing suggested the name 'hysteresis' for this phenomenon.

It can easily be proven that this magnetic lag is a necessary and sufficient condition for a resultant transformation of energy which accompanies any cyclic process of magnetization. If we plot a curve between the values of magnetizing field *H* and the corresponding intensity of magnetization *I*, as in Fig. 1, then the area enclosed by the curve representing a complete cycle of changes represents the energy expended on the material, as was shown by Warburg in 1881. The energy expended appears in the material in the form of heat, and this transformation of energy is of enormous importance industrially. Every electric

FIG. 1.



Hysteresis loop.

generator, motor and transformer, as well as many other pieces of apparatus employing iron or steel in which the magnetization is changing, is an example of this fact. In all such apparatus employing iron cores, very careful consideration must be given by the designer to the problem of keeping down this magnetic hysteresis to the lowest value consistent with the other considerations of design. Not only does the hysteresis cause a great waste of power, but on account of the development of heat it helps to put a limit to the capacity of the apparatus, for the rated capacity is usually based upon the permissible rise of temperature.

According to the reports of the U. S. Bureau of the Census,

there were manufactured in this country in 1905 66,698 transformers with a total capacity of 970,908 horsepower. I have estimated that the core losses in these transformers would not be less than 7800 kilowatts, and with a cost of power of one-half cent per kilowatt-hour they would consume in core loss in one year power to the value of $340,000. Between 1900 and 1905 the yearly output of transformers more than doubled. If we assume that this rate of increase has been constant, we can compute the total number of transformers in use to-day and the power wasted in them annually through core loss. An estimation on this basis indicates that there is now expended in this country to supply core losses in transformers alone, power costing nearly $4,000,000 annually.

As the output of motors annually is about two-thirds the output of transformers, measured in power rating, and as the output in generator capacity is about 50 per cent. greater than the output of transformers, it is evident that the total expenditure for core losses must reach an enormous sum, probably over $10,000,000 annually.

All of this enormous waste is not due to hysteresis, since eddy currents in the core conspire with the hysteresis to make up the total. The eddy-current loss, however, is usually the smaller part of the total, so that the magnetic hysteresis must accept the responsibility for dissipating each year the major part of this vast expenditure of energy in the form of heat. If the heat could be stored up for the winter months and utilized in heating our buildings a prodigious saving might be accomplished and the depletion of our coal supply somewhat delayed.

Not only the industrial importance of hysteresis, but also the scientific interest which its discovery aroused, has led to a great many investigations into the causes of the phenomenon, the conditions which affect its value, and the best methods of measuring it.

The methods of measuring hysteresis are numerous, and I shall not take time to discuss all of them. I have already pointed out that the area of the hysteresis loop obtained by plotting a curve between H and I represents the energy expended per unit volume of material under the particular conditions of the experiment. The constant of proportionality depends of course upon the scale and units employed, and is easily determined. If the

flux density in the material, B, be used as a co-ordinate of the curves, instead of I, the area of the loop will still represent the energy expended, but the constant of proportionality will be altered. Consequently any method of measuring the corresponding values of either pair of quantities will suffice to plot a hysteresis loop and thus determine the energy expended in the cycle. One well-known method is by use of the magnetometer, whose deflections give a measure of I for any applied H. In this method the specimen is preferably in the form of an ellipsoid, or of a long thin wire.

Another method employs a ballistic galvanometer connected to a coil of wire surrounding the specimen, the throw of the galvanometer produced by any change in the magnetizing field being a measure of the corresponding change of magnetic flux in the specimen. It is desirable in this method to have a closed path of magnetic material, and the specimen is either chosen in the form of a ring, or else massive yokes are used to complete the magnetic circuit. Various forms of ingenious apparatus have been devised for mechanically drawing the hysteresis loop, and there are also a number of commercial permeameters in the field for facilitating these measurements, such as the apparatus of Koepsel, Esterline, Carpentier, or Bruger.

The determination of hysteretic loss of energy by drawing the loop is a tedious and inconvenient process, since the curve is usually determined point by point, and the area must then be measured by planimeter or other slow means. Consequently methods and apparatus have been devised for giving the desired results directly from the instrumental readings.

In the Ewing hysteresis tester, the specimen is rotated between the poles of a permanent magnet, which experiences a torque in the direction of rotation due to the hysteresis in the specimen. The magnet is displaced until the torque is balanced by gravity and the deflection read by means of a pointer moving over a graduated scale. The flux density is determined principally by the length of the specimen and is little influenced by the cross-section, within certain limits. If specimens are cut accurately to a prescribed length, comparative readings are thus obtained for one particular flux-density.

The Blondel-Carpentier instrument is similar in principle, but uses a ring specimen and a rotating U-magnet. The torque

exerted on the ring is opposed by a spring, and is indicated by a horizontal pointer.

In both of these instruments, if the rotation takes place at a low speed, as when turned by hand, the eddy currents have very little effect and the torque is approximately proportional to the hysteresis. The usual flux-density obtained in the Ewing apparatus is 4000 gausses, and in the Blondel tester 10,000 gausses.

Each apparatus is subject to the same limitations, such as giving results for only one flux-density, and requiring a standard sample of known constants for comparison.

The most direct means of measuring hysteresis in general, without bringing in eddy current effects, is supplied by the ballistic dynamometer. This instrument differs from the ordinary electrodynamometer in having a moving coil with a long period of swing. In using it, the current which produces the magnetizing field is sent through the fixed coils, while the moving coil is connected to a winding which surrounds the magnetic flux. Upon reversal of the magnetizing current, the induced current in the circuit of the moving coil produces a temporary deflection or throw in the instrument which can be shown to be proportional to the hysteretic energy for the half-cycle.

Just as a galvanometer measures current in its ordinary use, but quantity of electricity when used ballistically, so the dynamometer measures energy by its ballistic throw, but power, or rate of energy, when used with currents giving steady deflections.

The ballistic dynamometer thus gives by a single observation the quantity desired. This simple and elegant method of measurement was first proposed by Searle,[1] and has lately been utilized by Rice and McCollum.[2]

The core losses encountered in electrical apparatus do not consist of hysteresis alone, but are augmented by the presence of eddy currents in the iron. The magnitude of the eddy currents is diminished by laminating the core, *i.e.*, by building it up of separate sheets, which are electrically insulated by a thin coating of japan, or sometimes left without other insulation than that afforded by the coating of oxide which usually forms the surface of the sheet. In the commercial testing of core material it is not merely the determination of hysteresis which is desired, but the

[1] G. F. C. Searle, Electrician, 1896, xxxvi, 800.
[2] M. E. Rice and Burton McCollum, Phys. Rev., 1909, xxviii, 132.

determination of the total power consumption due to both hysteresis and eddy currents under definite conditions of flux density and frequency of alternation. Testing methods have consequently been employed which subject the material to conditions very similar to those met with in service.

In general, alternating current is used to create a magnetizing field, and the power required to continually reverse the magnetization of the iron is measured by a wattmeter. The material is sometimes used in the form of rings, and to obviate the necessity of winding a magnetizing coil on each specimen, apparatus has been built by Möllinger[3] and by Esterline[4] in which the winding is divided, so that the specimen can be inserted and taken out. A ring form has the advantage that an unbroken magnetic circuit of the material is secured, and there is little opportunity for magnetic leakage, or variation of the flux between successive parts of the magnetic circuit. On the other hand, to secure uniformity of the flux across the section of the ring, it is necessary that the radial breadth of this section be small in comparison to the diameter of the ring. In the case of sheet material, this condition can only be fulfilled by making the rings of unwieldy size or else very narrow. The latter alternative is objectionable because the material near the cut edge is hardened by the cutting, and in a narrow strip the average value is too greatly influenced by this hardened portion.

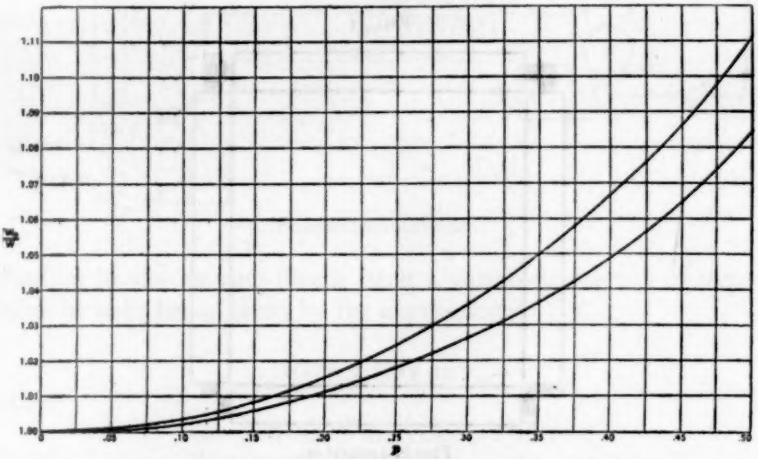
In Fig. 2 is shown the effect of the uneven distribution of flux found in rings of small diameter. One curve is given for rings of square section, and one for circular section. Each curve gives, for different relative dimensions, the ratio of the hysteresis for a uniform distribution of flux to that actually found. In computing these values it is assumed that the permeability of the material is uniform, but this is not always true, since the permeability is itself dependent upon the flux-density, having its highest value for a medium flux-density, the particular value of which varies from one specimen to another. When using a flux-density lower than this particular value, the distribution of flux is more uneven than assumed in the curves, and the resulting errors will be greater, whereas for higher flux-densities the reverse is the case.

[3] J. A. Möllinger, Electrot. Zs., 1901, xxii, 379.
[4] J. W. Esterline, Prac. Am. Soc. Testing Materials, 1903, iii, 288.

An apparatus was introduced by Richter[5] for testing entire sheets of iron. It consists of a thin magnetizing coil in the shape of a barrel, with a slot left at one point for the introduction of the sheet. The sheets are shoved around until the two ends come in contact, forming a closed magnetic circuit. This method obviates the necessity of cutting up samples, wastes no material, and gives at once the average value of the whole sheet. It has the disadvantage of bending the sheet, which may alter the quantity sought.

The Epstein apparatus makes use of straight strips which are assembled in bundles and placed in four solenoids forming

FIG. 2



Curves showing ratio of hysteresis in uniform field to actual hysteresis for rings of rectangular (upper curve) and circular (lower curve) cross-sections; p is the ratio of radial width o section to diameter of ring.

the sides of a square. The magnetic circuit is interrupted at the corners by pieces of cardboard inserted between the ends of the bundles. This method has been adopted in Germany by the Association of Electrical Engineers, and their standard test is the determination of watts per kilogram at a flux-density of 10,000 gausses and a frequency of 50 cycles per second.

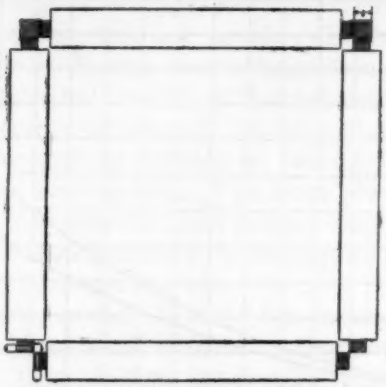
A modification of the Epstein apparatus has been developed at the Bureau of Standards by Mr. J. V. S. Fisher and the

[5] R. Richter, Electrot. Zs., 1903, p. 341.

speaker.[6] The modification consists principally in mounting the bundles with their faces, instead of their edges, toward the centre of the square, and making good magnetic joints at the corners by the aid of special corner pieces. This arrangement enables wide strips to be used while keeping the radial breadth of the core small, so that the distribution of flux is very uniform; the avoidance of gaps in the magnetic circuit keeps the magnetizing current low and thus distortion of the wave-form can be avoided while using a much smaller quantity of iron. The reason for this will be made clear below.

The plan of this apparatus is shown in Fig. 3, and Fig. 4 gives a diagram of connections. Each solenoid consists of a mag-

FIG. 3.



Plan of apparatus.

netizing coil and a secondary winding, the windings of the four solenoids being connected respectively in series. The source of current is connected to the magnetizing coils through the wattmeter and ammeter. The secondary windings are connected to the potential circuit of the wattmeter through a non-inductive resistance R_1. When used in this way the wattmeter deflections are a measure of the energy expended in the core and the secondary circuits, but do not involve the copper loss in the magnetizing coil. Another circuit connected to the secondary coils

[6] A fuller description of this apparatus is given in Reprint No. 109 from the Bulletin of the Bureau of Standards.

contains a voltmeter and a non-inductive resistance, R_2. A frequency meter is connected across the mains.

The purpose of the voltmeter is to determine the magnetic flux in the material tested. The voltage induced in the secondary

FIG. 4

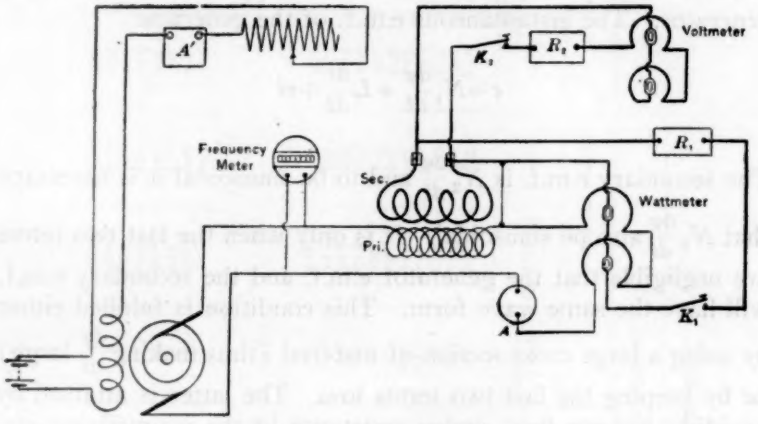


Diagram of connections.

winding by the varying flux is itself a variable quantity, its mean value in volts being given by the expression:

$$Em = 4\,Nn\varphi\ 10^{-8}$$

where

n = frequency in cycles per second
N = number of turns
φ = flux in maxwells.

Most types of voltmeters measure, not the mean value of the voltage, but the effective, or r.m.s. value. The ratio of the effective to the mean value is called the form-factor. Consequently if

f = form factor of secondary voltage
A = area of cross-section of specimen
B = flux per unit area
E = effective voltage

we have

$$E = 4\,fnNBA\ 10^{-8}$$

It is preferable to work with a wave of definite shape, so that f has a specified value. The sine wave is the most suitable and for this f has the value $\frac{\pi}{2\sqrt{2}} = 1.1107$.

In order to have a sine wave of secondary e.m.f. it is not sufficient merely to have a sine wave of applied e.m.f. from the generator. The instantaneous e.m.f. of the generator

$$e = N_1 \frac{d\varphi}{dt} + L\frac{di}{dt} + ri$$

The secondary e.m.f. is $N_2 \frac{d\varphi}{dt}$ and to be sinusoidal it is necessary that $N_1 \frac{d\varphi}{dt}$ also be sinusoidal. It is only when the last two terms are negligible that the generator e.m.f. and the secondary e.m.f. will have the same wave form. This condition is fulfilled either by using a large cross-section of material (thus making $\frac{d\varphi}{dt}$ large) or by keeping the last two terms low. The latter is attained by avoiding leakage flux, undue resistance in the magnetizing circuit and undue reluctance in the magnetic circuit, since the latter increases the magnetizing current i.

This condition also puts a limit to the values of B and n which may be used without wave-distortion, since too low values of either will reduce $\frac{d\varphi}{dt}$ too much, and values of B approaching magnetic saturation will increase i unduly.

Table I gives some of the results which have been obtained with this apparatus.

An investigation by Steinmetz in 1892 led to the establishment of an empirical relation connecting the hysteretic loss of energy with the maximum value of the flux-density reached during the cycle. That is, if the flux-density alternates between the values $+B$ and $-B$ the loss of energy per cycle and per unit volume is equal to ηB^{κ} where η is a constant depending upon the material, and to the exponent κ was assigned the value 1.6. Later investigations have shown that this relation is not rigorous, that the exponent κ is not constant, but departs widely from 1.6 at very high and very low flux-densities; and that the loss at high flux-densities is more correctly expressed in terms of $I^{1.6}$

TABLE I.—ORDINARY STEEL.

Designation	Thickness	Ergs per Gram per Cycle								Watts per Pound at 60 Cycles and 10000 gausses			x	y
		10000 gausses				5000 gausses								
	cm.	60~	30~	Hysteresis	Eddy currents	60~	30~	Hysteresis	Eddy currents	Eddy currents for gage 29	Hysteresis	Total		
E	0.0476	971	853	735	236	304	275	246	58	0.36	2.00	2.36	1.58	2.02
F	0.0280	766	716	666	100	247	233.5	220	27	0.44	1.81	2.25	1.60	1.88
G	0.0394	773	668	563	210	247	220	193	54	0.47	1.53	2.00	1.54	1.96
H	0.0307	558	485	412	146	177.5	158	138.5	39	0.54	1.12	1.66	1.58	1.00
J	0.0318	543	442	341	202	166.5	139	111.5	55	0.70	0.93	1.63	1.62	1.88
K	0.0282	518	456	394	124	162	146	130	32	0.54	1.07	1.61	1.61	1.90
L	0.0346	565	473	381	184	175	150	125	50	0.535	1.035	1.57	1.61	1.88
B_1	0.0338	554	454	354	200	173	144.5	116	57	0.61	0.96	1.57	1.61	1.81
M	0.0335	550	461	372	178	173	150	127	46	0.55	1.01	1.56	1.55	1.95
N	0.0340	531	426	321	210	161	133	105	56	0.63	0.87	1.50	1.62	1.90
P	0.0437	518	426	334	184	157	132	107	50	0.335	0.91	1.24	1.64	1.88
						SILICON STEEL.								
Q	0.0361	357	330	303	54	113	105.5	98	15	0.14	0.82	0.96	1.63	
R	0.0315	330	309	288	42	104	98.5	93	11	0.15	0.78	0.93	1.64	
S	0.0452	350	314	278	72	108	99	90	18	0.12	0.76	0.88	1.63	
T	0.0338	310	280	250	60	96	87	78	18	0.18	0.68	0.86	1.68	
U	0.0346	312	291	270	42	98	92	86	12	0.12	0.74	0.86	1.66	
V	0.0310	298	275	251	47	92	85.5	79	13	0.17	0.68	0.85	1.68	
W	0.0305	240	218	197	43	74.7	68.5	62.3	12.4	0.16	0.54	0.70	1.67	
X	0.0439	265	232	200	65	80.8	72.5	64.2	16.6	0.12	0.54	0.66	1.65	

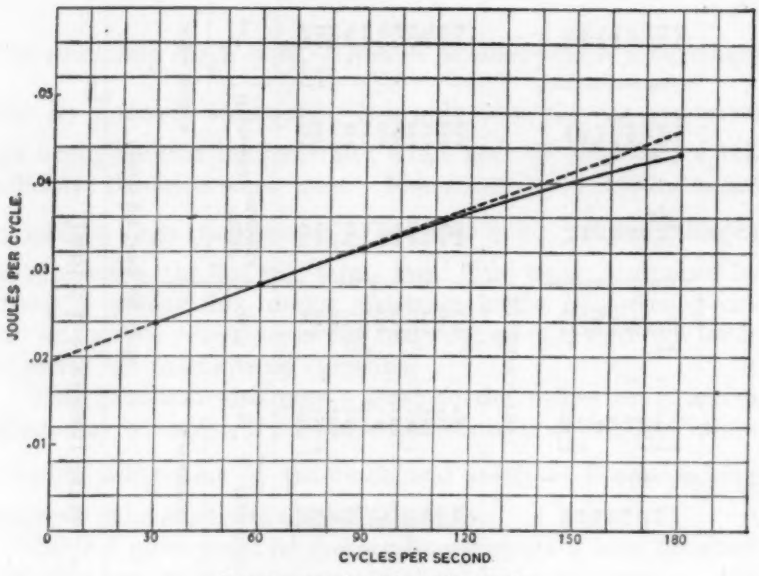
where I is the intensity of magnetization and is related to the flux-density by the equation

$$B = H + 4\pi I$$

For moderate flux-densities, and more especially in the region of industrial operation, the Steinmetz Law is a very close approximation to the truth and has been of great usefulness.

When alternating current is used for producing magnetiza-

FIG. 5.



Loss per cycle for different frequencies.

tion we must consider not only the hysteretic loss of energy but also that due to eddy currents. If a sine wave be used, the total power per unit volume is given by

$$W = \eta n B^{\kappa} + \zeta n^2 B^{\gamma}$$

where n is the frequency in cycles per second, and ζ a constant depending upon the electrical conductivity of the material and its dimensions. Since the hysteresis loss is proportional to the frequency and the eddy current loss to the square of the frequency, these two components of the total loss can be separately

determined by observations at two or more frequencies. Fig. 5 is a curve plotted between loss per cycle and frequency. For the lower frequencies this is sensibly straight, and by projecting back to the axis the hysteresis per cycle is given by the intercept on the axis. The exponent y has been shown on theoretical grounds to have the value 2 for an infinite thin sheet, and under practical conditions it approximates closely to this value for sheet iron or steel. The values of the exponents κ and y can be determined by measuring the losses at different flux-densities. The values of y given in Table I are computed from measurements made at 5000 and 10,000 gausses, the separation of losses being

TABLE II.—VALUES OF HYSTERETIC CONSTANT.

Material	η	Authority
Hard tungsten steel	0.058	Steinmetz
Hard nickel	0.039	Steinmetz
Hard cast steel	0.025	Steinmetz
Magnetic iron ore	0.020	Steinmetz
Forged steel	0.020	Steinmetz
Two-mil steel wire	0.016	Lloyd
Cast iron	0.013	Steinmetz
Soft nickel	0.013	Steinmetz
Cast steel	0.012	Steinmetz
Cobalt	0.012	Steinmetz
Heusler alloy I	0.012	Gumlich
Electrolytic iron	0.009	Schild
Soft machine steel	0.009	Foster
Annealed cast steel	0.008	Foster
No. 36 iron wire	0.005	Lloyd
Ordinary sheet iron	0.004	Lloyd
Pure iron	0.003	Gumlich
Heusler alloy II	0.0024	Gumlich
Soft iron wire	0.002	Foster
Annealed iron sheet	0.002	Lloyd
Ingot iron	0.0016	Lloyd
Best annealed sheet	0.0010	Lloyd
Silicon steel sheet	0.0010	Lloyd
Silicon steel	0.0009	Gumlich
Best silicon steel	0.0006	Lloyd

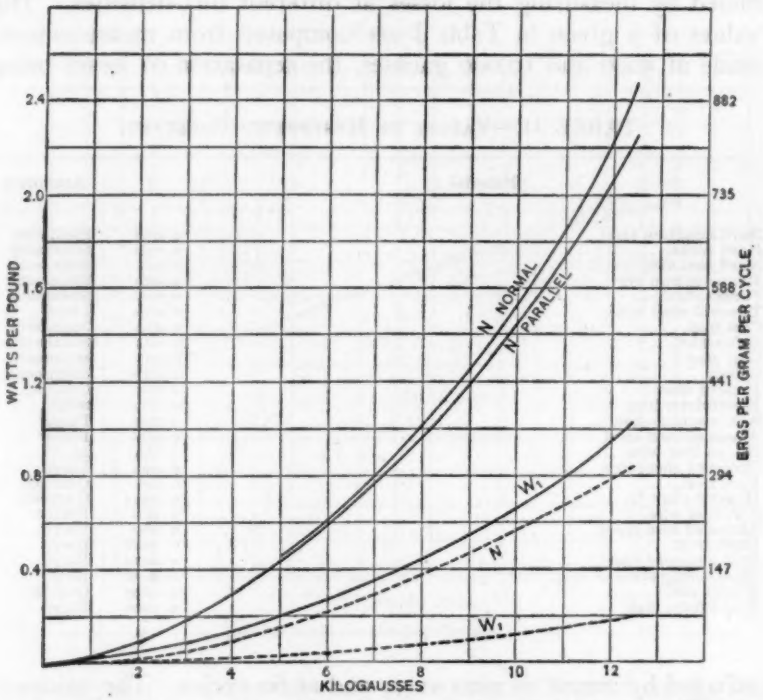
effected by means of runs at 30 and at 60 cycles. The values of η are computed for 10,000 gausses. In Fig. 6, the solid curves show the relation between core loss and flux-density for two specimens. For specimen N a difference was found according as the sheet was magnetized parallel or normal to the direction of rolling. The dotted lines give eddy current loss at sixty cycles.

Table II gives values of η collected from various sources, for a wide variety of materials.

The importance of hysteresis to the manufacturer of elec-

trical apparatus has been already pointed out. Since an improvement in both efficiency and capacity results from diminishing the core loss, efforts are constantly being directed toward the improvement of the core material. The best material will not only have a low hysteretic constant, but must also have a low electric conductivity in order to suppress eddy currents. When the difference between hard steel and soft iron was first recorded,

FIG. 6.



Dependence of losses on flux density, showing the difference when sheet is magnetized parallel or normal to the direction of rolling. Full lines show total loss, dotted lines the eddy-current loss. Sixty cycles.

men jumped to the conclusion that the softer and purer the iron could be obtained, the better would be the results. The annealing of electric sheets was therefore universally practised and Norwegian and Swedish iron were universally demanded. The later preparation of electrolytic iron and of chemically pure iron has shown that increased purity does not improve the properties of the iron. On the other hand investigators have examined more

closely the effects of different impurities, and it has been found that certain impurities are beneficial. As early as 1896 a patent was taken out in this country by J. F. Kelly,* covering a core in which the percentage of silicon was unusually large. It had been found by Kelly that a slight increase in the amount of silicon, not exceeding 0.03 per cent., made the sheets more stable, so that the hysteresis did not increase after the apparatus was put in service, a phenomenon which was quite common in soft iron and the mild grades of steel previously used. A few years later, Hadfield, in England, experimented with a number of alloy-steels and it was found that either aluminum or silicon would greatly improve the magnetic quality when introduced in the proportion of 2 or 3 per cent. Silicon-steel has proved the most useful industrially and in 1903 Hadfield † was granted a patent covering the use of this ingredient to the extent of 1 to 5 per cent. Later patent issues to him also cover the admixture of aluminum and manganese, as well as special processes of annealing aimed to secure the best characteristics for electrical use. Silicon-steel is very generally used to-day for transformer cores, and is made by several mills in this country. The proportion of silicon varies between 2.5 and 4.0 per cent., the exact percentage not being a matter of importance. The specific conductivity of this material is about one-fourth that of ordinary annealed steel, and the eddy current loss is reduced in the same proportion. The hysteresis loss is about two-thirds to three-fourths the value in ordinary transformer steel, which is another substantial gain.

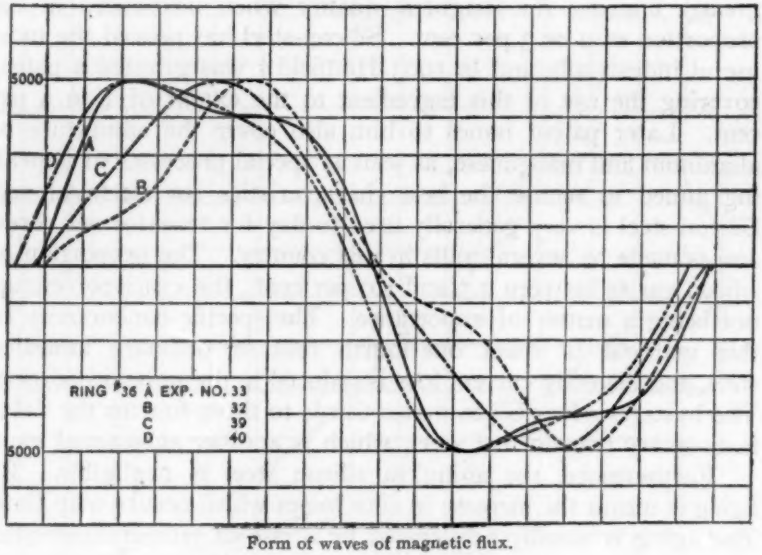
Furthermore, the aging in silicon steel is negligible. By aging is meant the increase in core losses which occurs with time. The aging is usually accelerated by a rise of temperature, even the working temperature of the apparatus having an action of this kind. Specimens may be aged artificially by keeping them at a temperature of 100° C., a few weeks at that temperature being sufficient to bring out whatever tendencies of this kind may be inherent in the material. Sheets which have been subjected to heat treatment for the purpose of making them unusually soft, seem especially subject to aging, and much of the material formerly used for cores was very objectionable on this score. The speaker has tested electrical sheet steel in which the aging amounted to as much as 25 per cent. in 100 hours and

* J. F. Kelly, U. S. Patent No. 570310, October 26, 1896.
† R. A. Hadfield, U. S. Patent No. 745829, December 1, 1903.

67 per cent. in 500 hours, the material being maintained at 90–100° C. On the other hand, none of the silicon-steels tested has shown an increase of as much as 5 per cent.

Experiments have also been made looking toward the utilization of silicon-steel in the cores of generators and motors, but not with entire satisfaction. Silicon-steel has a high permeability in weak fields, making it especially suitable for series transformers, but its permeability falls off rapidly at high magnetizations, such as are found in the teeth of generator and motor

FIG. 7.



Form of waves of magnetic flux.

cores, and it is difficult to reach the necessary flux density. Moreover, the mechanical properties of this steel are a disadvantage, for it is hard and in a sense brittle. It rapidly dulls punches, dies and other cutting tools, and the dies used for generator and motor stampings are not so simple as those used for transformers. Where the metal is subject to continual vibration, it is in danger of breaking, and the teeth of the core have been known to snap off.

While no other alloy-steel has proved of such industrial importance in regard to its hysteresis value as silicon-steel, there

are other alloys which have interesting and useful properties. Tungsten steel, owing to its high coercive force, has been largely used for permanent magnets, especially where constancy is necessary, as in the magnets of measuring instruments. Since a high coercive force is accompanied by a large hysteresis loss, such alloys as this are most unsuitable for any purpose except permanent magnets. The value of the hysteresis loss varies with the amount of carbon present as well as with the tungsten, and Swinden[7] has recently shown that the maximum hysteresis for an alloy with 3 per cent. of tungsten is obtained when the carbon amounts to 0.5 per cent.

Chromium steel has properties very similar to tungsten steel, and is used for the same purposes.

Various nickel-steels have been investigated, and some of them show remarkable properties. Hopkinson found that an alloy containing 24.5 per cent. nickel was non-magnetic at ordinary temperatures, but when cooled below 0° C. it became magnetic and remained so upon returning to room temperature. If heated to 600° C. it again lost its magnetic properties, and did not recover them without another cooling. The magnetic changes were thus irreversible with respect to temperature. The density of the material was also found to follow an irreversible cycle, having the value at room temperature of 7.97 Gm. per c.c. when in the magnetic condition, and 8.15 Gm. per c.c. when non-magnetic.

Other experimenters have since examined a large number of nickel-steels. Osmond found that an alloy with 29 per cent. nickel was non-magnetic. Barrett and Brown state that the addition of 5 per cent. of manganese to an alloy high in nickel will make it non-magnetic, although the addition of 5 to 8 per cent. of manganese alone to ordinary steel does not obscure its magnetism. Nagaoka and Honda worked with a series of nickel alloys of different composition, and found that with 25 per cent. Ni the alloy was almost non-magnetic. They also found a remarkable change in the dimensions of these alloys when magnetized. The phenomenon of magnetostriction is not new, it being well known that iron and steel lengthen, while nickel contracts in the direction of magnetization. The addition of

[7] T. Swinden, Electrician, 1909, lxii, 830.

nickel to steel, however, produces an increased lengthening. Moreover, in iron the lengthening is accompanied by a lateral contraction, so that the change of volume with magnetization is very small. In the nickel-steels, however, it is relatively large, a 29 per cent. alloy giving the maximum effect, which was about 50 parts in one million for the fields used. Twenty-nine per cent. of nickel appears to represent a critical point in composition, as other physical properties showed peculiarities in this specimen, and with higher nickel content the temperature effects are reversible.

Hadfield found that a steel containing over 20 per cent. of manganese was non-magnetic, and the manganese can be reduced as low as 7 per cent. when 2 to 8 per cent. of aluminum or silicon is added.

A non-magnetic steel is also obtained by alloying 17 per cent. of aluminum with iron. The explanation of all of these non-magnetic steels is probably that the temperature of transformation lies below ordinary temperatures.

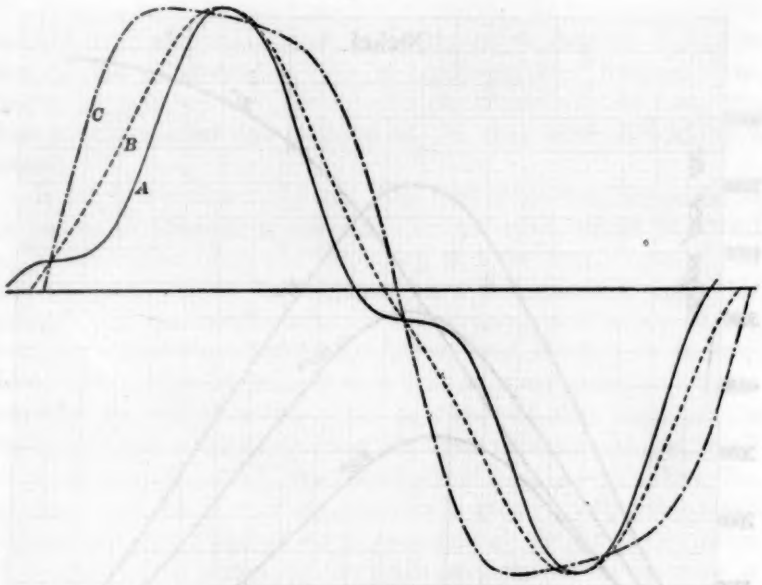
Alloys of arsenic, of antimony and of bismuth with electrolytic iron have recently been investigated by Burgess.[8] A 2 per cent. bismuth alloy showed high permeability, although bismuth is itself diamagnetic. The alloy containing 3.86 per cent. of arsenic not only showed high permeability, but the hysteresis was only about one-half that for Swedish iron.

Of equal interest with the non-magnetic nickel-steels, and of great importance in the theory of magnetism, are the magnetic alloys of non-magnetic metals. Foremost among these are the Heusler alloys, composed of aluminum, copper and manganese. It was at first supposed that the best combination was obtained when the manganese and aluminum entered in the ratio of their atomic weights, *i.e.*, about two to one, but the later work of Preusser[9] has shown that the most magnetic alloys are obtained with 12 to 13 per cent. of aluminum, regardless of the percentage of manganese. The earlier idea that the copper acted simply as a solvent or carrier for a definite combination of the other two metals has consequently been abandoned, and it is now believed that the copper plays an important rôle.

[8] C. F. Burgess and J. Aston, Trans. Am. Electrochem. Soc., 1909, xv, 369.
[9] W. Preusser, Thesis, Marburg, 1908.

The hysteresis of the Heusler alloys is not markedly different from that of iron. The values vary with the composition and heat treatment. Annealing from an appropriate temperature will greatly decrease the hysteresis, while other treatments may result in an enormous increase.[10] Alloys of copper and manganese with tin, with arsenic and with antimony are also ferromagnetic, but to a less degree than those just considered.

FIG 8



Form of waves of magnetic flux.

Most of the salts of the magnetic metals show themselves to be paramagnetic but the permeabilities are very small. A few of the compounds of iron, however, show ferromagnetic properties. Thus the mineral magnetite, which is an oxide of iron, was the original lode-stone, and its hysteresis has been measured. Berndt [11] has found that ferric oxide and hydroxide exhibit marked hysteresis. The mineral pyrrotite has received much attention from Weiss, who has shown that crystals of this

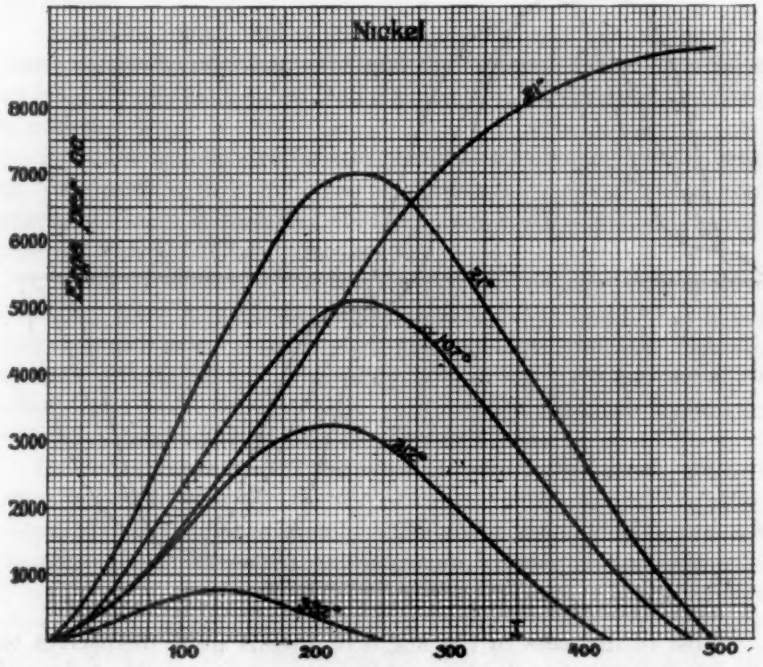
[10] Knowlton and Clifford, Phys. Rev., 1910, xxx, 125.
[11] G. Berndt, Phys. Zs., 1908, ix, 750.

material, which is a higher sulphide of iron, Fe_7S_8, are magnetic along one axis but not in a direction normal to this axis.

There are a large number of conditions which may affect the value of hysteresis in a given specimen, but time will not permit me to go fully into all of these, and I can but mention some of them.

Subjecting a specimen to mechanical stress will alter the

FIG. 9.



Rotary hysteresis at different temperatures. The curve for alternating hysteresis is given only for the temperature of 21°.

magnetic constants, the hysteresis usually being increased. If the stress be sufficient to permanently distort the metal, the hysteresis is permanently increased. Thus, any mechanical treatment, such as hammering, rolling, wire-drawing, etc., which mechanically hardens the specimen, will also harden it in the magnetic sense. The permeability is decreased and the hysteresis increased. The tempering of steel has a similar effect. Annealing, on the

other hand, will generally improve the magnetic qualities. Mechanical vibration has a marked effect on the hysteresis, as the molecular aggregations seem thereby to have greater freedom of adjustment, and follow more closely the magnetizing field. Not only does the previous mechanical treatment and heat treatment affect the magnetic quality, but the previous magnetic treatment will also have its influence upon the measured values, and a definite magnetic condition is best obtained by demagnetizing from a high flux-density.

When a point-by-point method of tracing the hysteresis loop is used, it is found that the shape of the curve depends upon the size of the steps used. This is attributed to "magnetic viscosity," and it has been shown that the changes in the magnetic flux continue after the changes in the magnetizing field have ceased.

It might be expected from this, that when magnetization is by means of alternating current, the hysteresis would be found to be dependent upon the frequency and the wave-form of the current used. Many investigators have experimented upon this subject, but the results are not concordant, and much of the work is vitiated by disturbing factors and insufficient precautions. The effect of frequency is still an open question. Some work by the writer a few years ago showed that there was a slight effect of wave form upon the hysteresis, though too small to be of any industrial importance even with very marked distortion of the wave.[12] The hysteresis is greater with a flat wave of flux than with a peaked wave, even though the maximum value of the flux is the same. If the wave be dimpled, the increase is much more marked, as a small loop is superposed upon the main loop. Figs. 7 and 8 show some of the wave forms used. The maximum flux in these experiments was determined by measuring the average value of the induced voltage.

The effects of temperature upon hysteresis constitute a somewhat complex group of phenomena. I have already referred to the permanent effect of subjecting magnetic material to higher temperatures—an effect which is made manifest when it returns to room temperature, and is known as aging. I want now to refer briefly to those effects which accompany a change of tem-

[12] The details of this work are given in Reprint No. 106 from Bull. of B. S., vol. v.

perature, but persist only while the new temperature is maintained. These effects are usually covered by the term temperature-coefficient.

While the variation of permeability with temperature has received much attention, data concerning the variations of hysteresis are not so plentiful. Many of the results published are concerned with the variations in hysteresis in a constant field and are consequently obscured by the variations in permeability. The

TABLE III.—EFFECT OF TEMPERATURE ON HYSTERESIS.

Material	Bmax.	Ergs per c.c. per cycle					Authority
		15°	100°	300°	500°	700°	
Iron	4000	1080	975	685	460	250	Wills
Iron	6000	2200	2200	1450	725	...	Wills
Tungsten steel (4.5 per cent.)	2000	9200	8900	5800	2200	...	Wills
Tungsten steel (4.5 per cent.)	6000	12000	11700	8000	3750	...	Wills
		−70°	20°	100°			
Soft wrought iron	2000	423	397	333	....	...	Thiessen
Soft wrought iron	5000	1720	1620	1520	....	...	Thiessen
Soft wrought iron	10000	5070	4600	4030	....	...	Thiessen
		−52°	17°	99°			
Crescent tool steel	14700	33850	31880	29600	....	...	Thiessen
		−65°	24°	100°			
Nickel steel (5 per cent.)	14900	43070	41860	39700	....	...	Thiessen
		20°	270°	275°	290°		
Swedish iron	3500	2690	2080	....	....	...	Kunz
Wrought iron	3500	3100	....	2270	....	...	Kunz
Annealed charcoal iron	3500	2350	....	....	1600	...	Kunz

more recent researches have usually been conducted with definite flux-density, so that the results may be immediately interpreted.

Fleming and Dewar [13] made measurements upon Swedish iron down to the temperature obtained with liquid air, but found no variation with temperature, and their results were confirmed by Claude.[14]

[13] Fleming and Dewar, Proc. Roy. Soc., 1896, lx, 81.
[14] G. Claude, C. R., 1899, cxxix, 409.

Kunz,[15] working up to 800° C., found little change in steel up to 300°, but above that point there was a decrease. Soft iron, however, showed a steady decrease from room temperature up, the variation being linear. Some of his results are given in Table III. Wills[16] found similar effects with iron and tungsten-steel, and Thiessen[17] observed the same general trend for several materials between —70° and boiling water.

The work of Honda and Shimizu, reaching down to the temperature of liquid air, is perhaps the most illuminating which has been done on this subject. They found[18] that upon cooling Swedish iron the hysteresis decreases for low flux-densities, but increases for high flux-densities, and tungsten-steel behaved in the same way. In nickel and cobalt, the hysteresis was always increased by cooling. A recent research by Waggoner[19] shows that low-carbon steel behaves as stated just above for iron, while high-carbon steel behaves like nickel and cobalt. The change was least for a steel containing 1.1 per cent. carbon. He also found that the ratio of hysteresis to coercive force was constant for varying temperature and varying carbon content.

If instead of using a field which simply alternates in direction, we subject the magnetic specimen to a rotating field, such as may be produced by polyphase currents, a somewhat similar effect is produced, although the conditions are different. The material is now constantly magnetized, the field never being reduced to zero value, but the direction of magnetization is continually changed. Here again there is a lag of magnetization behind the magnetizing field, but the lag is a lag in direction, not in magnitude. This rotary hysteresis requires an expenditure of energy, as in the other case, but the amount of energy transformed is not the same, for a given value of the maximum flux-density. Eddy currents are produced in this case, also, and aid the transformation of energy into heat, but in what follows it is the energy due to the hysteresis that is to be considered. As in the case of the alternating field, the two sources of energy

[15] W. Kunz, Electrot. Zs., 1894, xv, 194.
[16] R. L. Wills, Phil. Mag., 1903, v, 117.
[17] A. H. Thiessen, Phys. Rev., 1899, viii, 65.
[18] K. Honda and S. Shimizu, Proc. Tokyo Phys.-Math. Soc. II, 1904, iii, 186.
[19] C. W. Waggoner, Phys. Rev., 1909, xxviii, 393.

loss can be distinguished by taking observations at two different frequencies.

The hysteresis in a rotating field was first observed by Baily,[20] who showed in 1894 that if a magnet was rotated about an iron armature, the latter experienced a torque in the direction of rotation. The armature used was finely laminated, in order to avoid eddy currents as far as possible.

The torque was measured by balancing it against a spring, and the hysteresis was thus determined. The hysteresis was found to increase with the flux density in moderate fields, but finally reached a maximum and decreased to zero when the field was made sufficiently intense. This result was obtained with both soft iron and hard steel, and was a confirmation of Ewing's theory, which explains magnetic phenomena by the mutual action of the elementary magnets which must be regarded as constituting a magnetic substance.

Beattie [21] made similar experiments upon nickel and cobalt, with similar results. In nickel, a maximum hysteresis loss of nearly 10,000 ergs per c.c. per cycle was observed with a magnetizing field of 340 gausses. In cobalt a maximum of about 36,000 ergs per cycle was observed and in both cases the plotted curves indicated that the hysteresis would reach zero if the flux were carried to the saturation value.

Beattie and Clinker [22] found that for iron the hysteresis reached a maximum for flux-density of 16,000 gausses, and then decreased reaching zero at about 25,000 gausses.

Schenkel [23] experimented by rotating the specimen in a steady field, and measured the torque by a form of transmission dynamometer. His results were similar to the above.

In 1908, Weiss and Planer [24] conducted some experiments with a rotating magnet which were somewhat more refined than the previous work. The specimens were in the form of disks, and when placed horizontally were subjected to a rotating field, but when placed vertically the effect was the same as an alternating field. Observations were made upon steel, iron, nickel, and

[20] F. G. Baily, Electrician, 1894, xxxiii, 516.
[21] R. Beattie, Phil. Mag., 1901, i, 642.
[22] R. Beattie and R. C. Clinker, Electrician, 1896, xxxvii, 723.
[23] M. Schenkel, Electrot. Zs., 1902, xxiii, 429.
[24] Journ. d. Phys., 1908, vii, 5.

pyrrhotite. They found, like previous observers, that for low fields the hysteresis was greater in the rotary field than in the alternating, but after passing a maximum the hysteresis in the rotating field finally decreased to zero as the material reached saturation. The ratio of rotary to alternating hysteresis was found to be largest for the weakest fields, and had a value of 3.6 for nickel. This ratio decreased continuously as the field was increased, except in the case of steel, where it at first increased and then decreased.

During the past year two researches have appeared showing the variation of rotary hysteresis with temperature.

Fuller and Grace [25] used two-phase alternating current to produce the rotary field, while Perrier [26] used apparatus similar to that of Weiss and Planer at Zurich. Both used electric heating coils to obtain the higher temperatures. Some of the results of Perrier are shown in Fig. 9.

Both sets of experiments show that the maximum hysteresis in the rotary field decreases with increasing temperature, and that this maximum is reached with a lower flux-density. Thus for iron at 580° this maximum occurs at 10,500 gausses, while at temperatures below 340° it occurs at about 16,000 gausses. Since the saturation value is also reduced by increasing the temperature, it was to be expected that the hysteresis would decrease to zero for a lower magnetization and this was found to be the case.

Perrier worked with nickel, magnetite and three kinds of iron and concluded that the ratio of the maximum values of the two kinds of hysteresis was characteristic of the material and independent of the temperature.

---

[25] W. P. Fuller and H. Grace, Phil. Mag., 1909, xviii, 866.
[26] A. Perrier, Thesis, Geneva, 1909.

THE PHYSICAL PRODUCTION OF LIGHT.

BY

EDW. P. HYDE.

(*Presented at a Stated Meeting of the Section of Physics and Chemistry, held Wednesday, March 16, 1910.*)

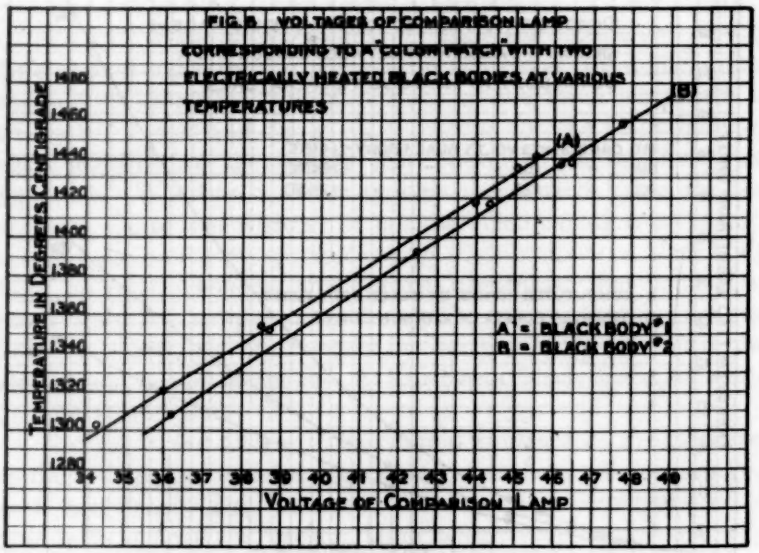
(*Concluded from Vol. CLXIX, page 466.*)

The first measurements on the black bodies consisted in determining the temperature of the black bodies at which they matched in color the standard carbon lamp at 75 volts. This was done by bringing the black body to various temperatures in the proper neighborhood and determining the voltage of the standard lamp corresponding to a color match. The accuracy with which this can be done is shown in Fig. 6, in which, however, the voltages refer to an auxiliary comparison lamp which when at 44.15 volts matched in color the standard carbon lamp at 75 volts. The results obtained on the two black bodies are given. For some reason the two black bodies though constructed in the same way and measured for temperature by thermocouples calibrated in the same laboratory, gave a difference in temperature of about 8° C. This difference may be due to the black bodies themselves, or possibly to variations in the comparison lamp. The latter assumption seems improbable since the comparisons with the two black bodies were made at about the same time. Moreover, computations for color match made from spectrophotometric comparisons of the standard lamp and black body No. 2 at the following temperatures, 1318°, 1335°, and 1432° C.,* gave respectively 1408°, 1414°, and 1417° C., with a mean of 1413° C. (1686° absolute) which agrees excellently with the value of 1412° C. read from the plot. It was impossible to carry the black body up to a sufficiently high temperature to match the

* Throughout this paper, unless specifically stated otherwise, temperatures will be given in Centigrade degrees on the ordinary scale, to which 273 must be added to obtain the absolute temperatures, which enter in the various black-body laws.

standard lamp at its next higher voltage, 100 volts. Having determined that the color of the standard lamp at 75 volts was the same as that of a black body at 1416° C. (mean of two black bodies) the next step was to determine the change in candle-power of the black body for 1 per cent. change in energy. This was done by measuring on a Lummer–Brodhun photometer set at a fixed distance from black body No. 1 the change in illumination produced by a restricted area of the rear wall of the black body when the latter was changed in temperature by a definite

FIG. 6.



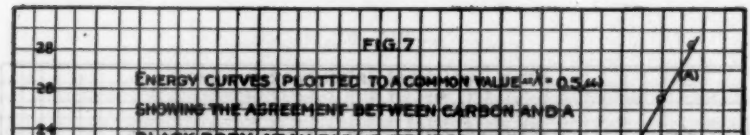
amount, measured by means of thermocouples. The increase in illumination, which is proportional to the increase in candle-power, was measured directly by varying the distance of a standard lamp; the increase in watts was computed from the temperature measurements by the use of the Stefan–Boltzmann law. The average value obtained by this method is given in Table II, opposite "Black body, observed." [13]

This coefficient obtained experimentally was checked by a direct computation on the assumption of the Wien equation of spectral energy distribution, and of Koenig's luminosity curves.

Although this method may conduce to large errors in the computation of absolute candlepower it is reasonably accurate for determining small changes in candlepower corresponding to some definite change in total emission, *i.e.*, some definite change in temperature.[14] The value for the coefficient obtained in this way is given in Table II, opposite "Black body, computed."

As was mentioned just above in connection with the measure-

FIG. 7.



ments on the black body, and also previously in the general description of the two new photometric methods, the color match criterion for agreement in relative energy distribution in the visible region of the spectra of two sources, was only trusted after having been duly justified by numerous spectrophotometric comparisons. Of the various substances investigated, as given in the first columns of Tables II to IV, all were examined spectrophotometrically with the exception of the "Helion" filament, which appeared so similar to carbon [15] as to make such a compari-

son unnecessary. Carbon was compared directly against black body No. 2 and showed no evidence whatever of excessive emissivity in any wave-length as compared with the black body. At the voltage of the carbon lamp corresponding to a color match with the black body at a given temperature the two spectrophotometric curves were identical throughout the entire visible spectrum to within the limits of accuracy of the measurements which was probably less than 2 per cent.

In Fig. 7, curve *A*, is shown the agreement in the two curves (coincident to within observational errors), for the black body and the carbon when at a color match with the standard lamp at 75 volts. The black body curve is computed for a temperature of 1416° C. from the Wien equation using the value $C_2 = 14500$. The carbon curve is the mean observed curve from the direct measurements against the black body at the three temperatures of 1318°, 1335° and 1432° C. assuming for the black body at each temperature the energy distribution given by the Wien equation. Whether or not 14500 is the correct value for the constant C_2, indeed whether or not the Wien equation is the correct expression for the spectral energy distribution of a black body is of no consequence in affecting the conclusion that at least at moderately low temperatures the visible spectrum of carbon can be very accurately represented by the visible spectrum of the electrically heated Lummer & Kurlbaum black body at some definite temperature.

Nichols [16] and Blaker [17] had found evidence of a depression in the red region of the energy curve of carbon, when compared with acetylene. This naturally led to a direct comparison of acetylene against the carbon lamp which had been previously compared with the black body. The result was to show evidence of an emission band at the extreme red end of the spectrum of the acetylene flame. The actual spectrophotometric curve obtained is not given because there was uncertainty as to the magnitude of the effect which was in a region of the spectrum difficult to measure. Further experiments were not made, owing to the writer's resignation from the Bureau of Standards. Moreover, the urgency of such further experiments was greatly lessened by the confirmation of the general conclusion regarding the emission band in the deep red region of the spectrum of acetylene which the writer had discovered as a result of an

analysis of the spectral energy curves of acetylene determined by Stewart.[18] The measurements of the flat acetylene flame indicated that the distribution in the visible spectrum is approximately that of a black body at about 2050° C.

Having shown that carbon exhibits no bands of pronounced emission in the visible spectrum, spectrophotometric comparisons were made between carbon and the other filaments when operated at the voltages determined for a match in color. These measurements gave no evidence whatever of pronounced selective emission in the visible spectrum of any of the substances examined. The spectrophotometric curves were perfectly smooth and in entire agreement with the curve for carbon, to within the errors of observation. In all of these measurements a "substitution" method was employed.

The absence of any indication of band emission in the visible spectrum of any of the metals examined would suggest as an interesting investigation a study of the reflectivity of tantalum, tungsten and osmium at various temperatures. Both tantalum and tungsten can now be obtained in strip form making possible such an investigation.

As stated previously, it was not feasible to operate the available black body at a sufficiently high temperature to compare its spectrum directly with that of carbon at the next arbitrarily chosen voltage of 100 volts. The next best thing to do was to compare spectrophotometrically the visible energy curve of carbon at 100 volts with its known curve at 75 volts and to compute from this derived curve the temperature which a black body should have in order to most nearly agree with the observed curve for carbon. Thus the temperature was computed (using Wien's equation with $C_2 = 14500$) at which a black body would emit the same relative energy at $\lambda = 0.7\mu$ and $\lambda = 0.5\mu$ as was observed for the carbon lamp. The complete visible energy curve of the black body at this temperature was then plotted and compared with the observed curve of carbon. These two curves (drawn in coincidence) are shown in Fig. 7, curve *B*, the temperature determined for the black body being 1613° C. The accuracy of this computed temperature is not insisted upon owing to certain errors which may enter and need correction in deducing relative energy curves from spectrophotometric observations when the luminosity curves of the two spectra under comparison

are different. The writer hopes to be able to publish a theoretical and experimental discussion of this question in the near future.

In a similar way the visible portion of the energy curve of the carbon lamp at 125 volts was determined by spectrophotometric comparison with the energy curve of the same lamp at 100 volts, and the temperature of the black body which would give a similar distribution was computed to be 1785° C. The observed curve for the carbon lamp and the computed curve for a black body at approximately 1785° C. are given in curve *C*, Fig. 7.

Having determined that carbon exhibits no marked emission bands in the visible, but rather conforms quite closely to the curve of a black body at both 100 volts and 125 volts, the other lamps were compared spectrophotometrically with the carbon lamp. None of these showed any marked deviation from carbon, but there was slight evidence in the case of osmium that the curve of the latter when showing the same relative distribution between the energy emitted at 0.7μ and that emitted at 0.5μ as compared with the carbon, dropped a little below that of the carbon at intermediate wave-lengths. This effect, which was so small as to lie almost within the errors of measurement was confirmed by the observation of the impossibility of making a perfect color match at high temperatures between carbon and osmium in the Lummer–Brodhun photometer. The osmium was relatively a little purplish, and the carbon a little greenish. For the other lamps, the effect, if present, was too small to be observed. Reference will be made to this phenomenon in a later paragraph.

It was, therefore, possible at the various temperatures at which measurements were made, and for all the lamps studied to secure color matches corroborated by spectrophotometric measurements with the possible slight exception noted above. Moreover it was possible at every voltage of the carbon lamp to find a black-body temperature at which the computed black-body curve was in agreement in the visible spectrum. Therefore, any selectivity which exists is not to be found in a pronounced emission band within the visible spectrum, but rather as a suppression or elevation of the visible spectrum as a whole compared with the infra-red region. It is to this form of selectivity that the two photometric methods apply. The data obtained by these two methods is contained in Tables II to IV.

In the first column of Table II, which contains the results obtained at a color match with the standard lamp at 75 volts, are given the various substances investigated. The second column contains the ratios (k) of the percentage change in candlepower to the percentage change in total energy radiated (taken as equivalent to the watts supplied). The third column contains the relative values of k expressed in terms of the value of k for untreated carbon as unity. By expressing the results in this way the relative differences among the different types of lamps are more readily seen.

TABLE II.

Average values obtained on lamps of each type at voltages corresponding to a "color match" with the standard lamp at 75 volts (black body at 1689° absolute).

Substances Investigated	k* (absolute values)	k (relative values)	Lumens per watt (absolute values)	Lumens per watt (relative values)
Black body { Observed	3.5	1.00	....	....
Black body { Computed	3.6	1.04	....	....
Untreated carbon	3.45	1.00	0.39	1.0
"Helion" lamp	3.45	1.00	0.38	0.95
Flashed carbon	3.35	0.97	0.41	1.05
Metallized carbon	3.4	0.98	0.41	1.05
Platinum	3.1	0.89	....	....
Tantalum	3.0	0.86	0.50	1.3
Tungsten	2.85	0.82	0.59	1.5
Osmium	2.85	0.82	0.72	1.85

*k is the per cent. change in candlepower corresponding to a change of 1 per cent. in watts. The relative values are in terms of $k=1$ for untreated carbon.

In the fourth column are given the lumens per watt, on the basis of the *international candle*, and in the fifth column are given the same quantities expressed in terms of the value for the untreated carbon lamp taken as unity. Tables III and IV contain similar data at the higher temperatures corresponding to a color match with the standard carbon lamp at 100 volts and 125 volts respectively.

The results are quite interesting. Thus it will be noticed (Table II) that when these various substances have the same distribution of energy in the visible spectrum the lumens per watt range from 0.39 to 0.72 in absolute value, or from 1.00 to 1.85 relatively.

If there were no relative selectivity, the lumens per watt would be the same for every type. There is marked evidence, therefore, that there is considerable selectivity among the different types of filaments, and it is interesting to note the order in which the filaments arrange themselves. A higher value of lumens per watt, as for example the value 1.85 for the osmium lamp as compared with 1.00 for the untreated carbon filament, indicates that when the osmium filament has the same distribution of energy in the visible spectrum as the untreated carbon filament, the spectral energy curve of the osmium filament drops off considerably in the infra-red as compared with the energy curve of the untreated carbon. In other words, the osmium radiates selectively in favor of shorter wave-lengths, that is, in favor of the visible spectrum, and is therefore a more efficient luminous radiator than an untreated carbon filament. It would appear from the table that the "Helion" lamp is, if anything, less selective in favor of shorter wave-lengths than the untreated carbon. The small difference, however, between 1.00 and 0.97, may be accounted for by experimental error, so that we might say that the "Helion" filament behaves very much like the untreated carbon filament. It should be explained, however, that the "Helion" filaments which were used in this invstigation were

TABLE III.

Average values obtained on lamps of each type at voltages corresponding to a "color match" with the standard lamp at 100 volts (black body at 1886° absolute).

Substances Investigated	k^* (absolute values)	k (relative values)	Lumens per watt (absolute values)	Lumens per watt (relative values)
Black body { Observed	....	....	....	....
Black body { Computed	3.25	1.06	....	....
Untreated carbon	3.05	1.00	1.5	1.0
"Helion" lamp	3.0	0.99	1.5	1.0
Flashed carbon	3.0	0.98	1.6	1.1
Metallized carbon	3.0	0.99	1.55	1.05
Platinum	2.75	0.90	....	....
Tantalum	2.6	0.86	1.7	1.15
Tungsten	2.55	0.84	2.0	1.35
Osmium	2.5	0.83	2.35	1.55

*k is the per cent. change in candlepower corresponding to a change of 1 per cent. in watts. The relative values are in terms of $k = 1$ for untreated carbon.

quite old and it is barely possible that the deposit of silicon had entirely disappeared and that we were simply studying the properties of the base carbon, which would readily explain the results obtained. The treated carbon and the gem filaments are more selective than the untreated carbon; the tantalum considerably more selective; the tungsten still more so; and finally, the osmium most selective of all. It is very striking that despite the relatively large experimental errors which may enter into these measurements, the filaments arrange themselves very closely in the same order of selectivity when we use the second method of determining selectivity as found by the first method.

TABLE IV.

Average values obtained on lamps of each type at voltages corresponding to a "color match" with the standard lamp at 125 volts (black body at 2058° absolute).

Substances Investigated	k^* (absolute values)	k (relative values)	Lumens per watt (absolute values)	Lumens per watt (relative values)
Black body { Observed	....	....	....	....
Black body { Computed	3.05	1.11	....	....
Untreated carbon	2.75	1.00	3.5	1.0
"Helion" lamp	2.7	0.98	3.6	1.0
Flashed carbon	2.65	0.98	3.7	1.05
Metallized carbon	2.75	1.00	3.7	1.05
Platinum	....	....	....	....
Tantalum	2.35	0.86	3.9	1.1
Tungsten	2.4	0.88	4.4	1.25
Osmium	2.4	0.87	4.9	1.4

* k is the per cent. change in candlepower corresponding to a change of 1 per cent. in watts. The relative values are in terms of $k = 1$ for untreated carbon.

Thus, in the second and third columns, the ratios of the percentage change in candlepower to the percentage change in watts is about the same for the untreated and for the "Helion" filaments. It is slightly less for the treated carbon and the gem filaments, and considerably less for platinum; somewhat less for the tantalum; and still smaller for the tungsten and osmium filaments. The only apparent discrepancy is that the tungsten filament has a lower coefficient than the osmium which is the reverse of what we found by the other method. This might readily be accounted for in two ways. In the first place, the

coefficients as given in the second and third columns are in no way as widely different as the values of lumens per watt given in the fourth and fifth columns, and a slight error in determining the coefficient might account for the difference in the relative results obtained by the two methods for the tungsten and osmium filaments.

In the second place, so far as I can see now, there is no definite reason why the relative quantitative results obtained by the two methods should be the same; for, granting that two filaments are selective as compared with a black body, the nature of the selectivity may be different. Thus, it may be that the energy curve of one filament is suppressed throughout the entire infra-red spectrum to approximately the same extent, whereas it may be that in the case of the other filament, the suppression may be exaggerated in some particular region of the infra-red spectrum. Such differences would seem sufficient to account for small quantitative differences in the selectivity as determined by the two methods.

The results obtained at the higher temperatures (Tables III and IV) are quite similar to those found at the lower point. By both methods the filaments arrange themselves in the same order as found at 75 volts, but the numerical differences are in some cases considerably smaller. Thus, at 75 volts, the lumens per watt of the osmium lamp is almost twice that of the untreated carbon lamp, whereas at 125 volts, it is less than one and one-half times that of the untreated carbon lamp.

Special attention should be called to the positions of the black body and platinum compared with the other substances studied. As was to be expected, the black body stands at one end of the list, all of the metals and carbon being selective with respect to it. There is considerable difference between the observed and computed values of "*k*," but this is only to be expected. The electrically heated hollow enclosure is not a *perfectly* black body; the determination of the true temperature by the use of thermocouples is fraught with difficulties; the exact form of the formula for the spectral energy distribution is not established beyond dispute, nor are the exact values of the constants known; finally, with the experimental difficulties on the one hand, and on the other, the uncertainty introduced in the computation by the necessary introduction of sensibility curves of the eye, it is

easy to account for the difference found between the observed and the computed values of "k." On account of this uncertainty, particularly at the higher voltages where it was impossible to make an experimental determination of "k," the values in the third column of each table are expressed in terms of the untreated carbon taken as unity, rather than in terms of the black body. The computed values of "k" for the black body at the higher temperatures are subject to more doubt than that given in Table II for the lower temperatures on account of the uncertainty of the temperature of color match at the higher voltages, as explained in a previous paragraph.

There is especial interest in the results obtained with platinum. As seen from Tables II and III it would appear to be less selective than any of the three metals, tantalum, tungsten and osmium, and yet it has ordinarily been referred to in much of the literature on the subject as being one of the most non-black metals. It is true that this departure from blackness may lie in its low emissivity and not in its selectivity, since it is known to emit but a small fraction of that radiated by a black body at the same temperature. This uncertainty as to what is meant in referring to a departure from blackness emphasizes the practical need of the distinction insisted upon in this paper between mere grayness and selectivity. So far as I know, the emissivities of tantalum, tungsten and osmium have never been determined with any degree of accuracy.

It is to be regretted that with the platinum lamps available up to the present time it has not been possible to determine the lumens per watt owing to the large conduction losses at the leading-in wires. An effort is being made to obtain this data at the present time.*

At this point the author desires to emphasize the fact that the numerical values given should not be trusted to too high an accuracy, as some of the lamps were used for quite a long period and showed marked evidence of deposit on the bulb. The uncer-

* Since the completion of this paper, data on the lumens per watt of platinum has been obtained. In Table II the lumens per watt for platinum should be 0.44 (absolute values) or 1.1 (relative values). In Table III the corresponding values should be 1.55 (absolute values) and 1.05 (relative values). These values of the lumens per watt, though not as accurate for platinum as for the other lamps, are consistent with the values of "k" found for platinum as compared with the other filaments investigated.

tainty becomes greater, of course, as the temperature increases, since the disintegration of the filament proceeds much more rapidly at the higher temperatures. The voltages at which the carbon filaments were operated to match in color the standard carbon at 125 volts were well beyond the normal values for the lamps, while the metal filament lamps, even at the highest temperature used, were still operating below normal voltage. However, some of the tantalum lamps showed marked deposit.

That no serious error was caused, however, by the deterioration of the lamps is shown in two ways. First, the filaments arrange themselves in the same order at the highest temperature as they do at the lowest, when they were operating well below their normal working temperatures and had suffered no disintegration. Secondly, the coefficients of change in candlepower, corresponding to 1 per cent. change in watts would not be affected to any great extent by a deposit on the bulb, and in almost every case as pointed out before, the filaments arrange themselves in the same order by both methods.

The one method, that of determining the lumens per watt, is the more sensitive when the experimental conditions are very carefully determined. The other method, while less sensitive, is, at the same time, much less dependent on the experimental conditions. Slight blackening of the bulb, appreciable loss of energy by conduction at the leading-in and anchor wires, and the errors in the wattage of the filaments introduced by bad contacts between the leading-in wires and the filament, would probably make but little difference in the values obtained for the coefficient of change in candlepower corresponding to 1 per cent. change in watts. These errors would probably be insignificant compared with the marked differences between the coefficients of the untreated carbon lamp and those of the osmium lamp, for example. There can be little doubt but that the arrangement of the filaments given in Tables II, III, and IV is substantially correct, though the numerical values found as a result of a more extended investigation might be somewhat different.

In interpreting the results given in the tables it may be stated that there is relative selectivity among the filaments beyond any doubt, but to what extent the high efficiencies of the metallic lamps are to be ascribed to selectivity and to what extent to the high temperatures at which the filaments operate, is by no means

immediately apparent from the data given. In order to arrive at any definite conclusion in regard to the amount of the selectivity one must know under what conditions of operation the filaments are at the same true temperature and at present there is no ready means available for making this determination.

If one could assume that when the filaments are at the same color, that is, when they show the same distribution of energy in the visible spectrum, they are operating at the same temperature, a quantitative estimate of the amount of selectivity would be possible at once, but there is no reason to believe that when the filaments show the same distribution of energy in the visible spectrum, all of them are operating at the same true temperature; in fact, there is much reason to believe that under this condition they are not operating at the same true temperature. By making an assumption which has been found to be true for platinum and which, though probable for most metals, has not been demonstrated to be true, it is possible to form an idea of the direction in which the difference in temperature will occur and to place a lower limit on the effect of selectivity in partly accounting for the high efficiency of the metallic filament lamps.

It will be noted from the data given in Table II that when the untreated carbon and osmium filaments are at the same color the lumens per watt of the osmium filament are 1.85 times the lumens per watt of the untreated carbon filament. This means that relatively more of the energy emitted by the osmium filament lies in the visible spectrum than in the case of the untreated carbon filament and that, therefore, the osmium filament is probably radiating selectively in favor of the shorter wavelengths. The numerical value of the effect depends, however, on the relative temperatures of the two filaments. If they are at the same temperature, the osmium is almost twice as efficient as the carbon lamp when they are both at the same low temperature corresponding to a color match with the standard carbon lamp when operated at 75 volts. If, on the other hand, the temperature of the osmium filament is higher than that of the carbon filament, then one cannot tell whether the increased efficiency of the osmium lamp is due to its selective emission, or to the slightly higher temperature at which it is operating.

Our knowledge of platinum radiation would lead one to expect, however, that the temperature difference is in the opposite

direction. If we imagine a radiating body which tends to exaggerate in its emission the energy of the shorter wave-lengths, that is, a body which emits a larger proportion of its total radiant energy in the visible spectrum as compared with a black body at the same true temperature, it is probable that this property of selective emission would obtain in the visible spectrum also, so that the emission in the blue would be relatively larger than the emission in the red as compared with the emission from the black body at the same temperature. If this assumption, which would seem to be true for platinum, is true for tantalum, tungsten and osmium, then the values recorded in the tables give, in every case, the lower limit of the effect of the selectivity on the efficiency of the filaments. For if, when at the same true temperature, the osmium radiates relatively more blue than red as compared with the untreated carbon,—considered approximately as a black body,—the color of the osmium light would be bluer than that from the untreated carbon, and it would be necessary, in order to bring the light of the carbon filament to a color match with that of the osmium filament to increase the voltage, that is, to increase the temperature of the carbon lamp. Such an increase of temperature would increase the lumens per watt for the carbon filament, and if it is found that, even at a color match, the lumens per watt of the carbon filament are only a little more than one-half the lumens per watt of the osmium filament, it would seem that if the two filaments were at the same true temperature the difference in efficiencies would be even greater. Hence, the numerical values given in the tables would seem to indicate a lower limit to the effect of selectivity on the efficiency. It is impossible to say how much more pronounced the selectivity would be if one could bring the filaments to the same true temperature.

It is possible that the difference between the working temperatures when the filaments are at the same color becomes more pronounced as the absolute temperature is increased and that this may account for the smaller differences in lumens per watt at the higher voltages as compared with the results obtained at 75 volts. At all events, one can see from Tables III and IV that if the assumption contained in the previous paragraph is true, an osmium lamp at the same true temperature as that at which an anchored oval treated carbon filament operates when

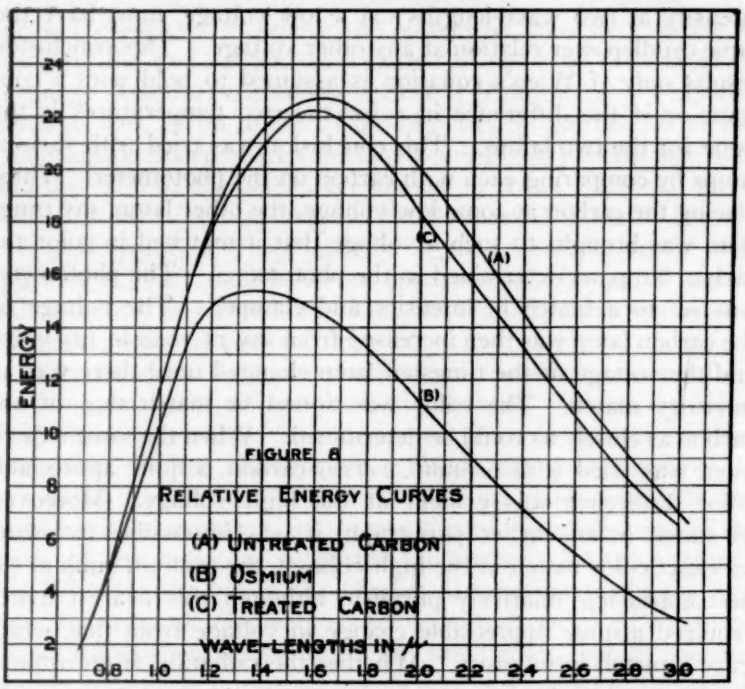
consuming about 3.1 watts per mean horizontal candle,—color match with standard carbon lamp at about 115 or 120 volts,—would show an efficiency higher than that of the carbon lamp by more than 35 per cent., or 40 per cent.; one cannot estimate how much higher the efficiency would be without a knowledge of the temperature difference which exists between the osmium and treated carbon filaments when at a color match.

From the data given in the tables for tantalum and tungsten, it is evident that for these, also, as well as for osmium, the selectivity would seem to play an important part in causing the high efficiency, particularly in the case of tungsten. It cannot be emphasized too greatly, however, that all of the deductions in regard to the effect of selectivity in partly explaining the high efficiency of the metallic filament lamps are based on the single assumption that if a black body and a metal are at such temperatures as to show the same distribution of energy in the visible spectrum (color match), the temperature of the black body is at least as high or higher than the temperature of the metal. This is true for platinum, the only metal that has been investigated, but the writer cannot say positively that it is true for other metals.

Reference has been made several times to the possible errors in the results owing (1) to the difference between the energy input and the energy radiated, and (2) to the changes in the lamps consequent upon burning, with the resultant deposit of carbon or metal on the bulb. The effect of each of these two sources of error has been considered, but it is desired to refer further to the first source enumerated in order to present an experiment of considerable interest as confirming the conclusions that had already been reached. Dr. Coblentz, of the Bureau of Standards, who, at the time of these experiments was engaged upon a study of the constant a for various substances, very kindly undertook, upon the request of the writer, to determine the infra-red energy curves of individual lamps of each of several types at stated voltages. The voltages which had been chosen were those for a color match with the standard carbon lamp (100 volts), as it was the desire of the writer to obtain from this experiment qualitative confirmation of the conclusion that if the infra-red curves of carbon and osmium, for example, were plotted to the same ordinate at the red end of the visible spectrum, say 0.7μ, the ordinates of the osmium curve would fall off con-

siderably in the longer wave-lengths. The results of the experiment for untreated carbon, treated carbon, and osmium, are shown in Fig. 8. Although the results of this experiment have already been published by Cady, Middlekauff and the writer,[19] and have been included also in a paper by Coblentz,[20] they are given again here since the experiment logically forms a

FIG. 8.



part of the present investigation, in connection with which it was undertaken. By reference to the curves of the figure it is seen that the indications afforded by the lumens per watt in Table III is entirely confirmed not only qualitatively, but even approximately quantitatively. When the two filaments have relatively the same distribution of energy in the visible spectrum, the energy radiated in the infra-red by the osmium is only about two-thirds that emitted by the untreated carbon. Flashed carbon

is intermediate between the two, though not much different from untreated carbon.

Although it is not the intention to give here an elaborate discussion of the radiation laws as applied to metals, there is one further point of interest that is pertinent to the present investigation. It is easy to deduce on the assumption of the Wien equation that two lamps which have some definite candlepower relation when at a color match (rigorously, the same relative intensity at two wave-lengths) at a low voltage, must have the same candlepower relation at any other voltage. This conclusion results only if Wien's equation is assumed to hold with α constant or if the difference in α for the two temperatures is the same for the two lamps. This conclusion was tried with various lamps by comparing each with carbon on the photometer. Thus, placing the carbon at some low voltage, the other lamp, say tungsten, was brought to such a voltage that it matched in color the carbon lamp, as determined in the photometer. The photometer was set to a match in intensity and clamped. The voltage of the carbon lamp was then increased from say 75 volts to 125 volts, and the voltage of the tungsten lamp changed until there was an *intensity* match. The color was found to match that of the carbon as closely as could be determined. When the same experiment was tried with osmium, *versus* carbon, a quite appreciable color difference was evident at the high voltage. Moreover, as stated in an earlier paragraph, it was impossible to secure an exact color match at the high voltage, the osmium lamp at the best appearing relatively purplish, although this nearest match required a quite appreciable change in voltage from that which gave a match in intensity. Whether the radiation from osmium is unique, or only different in degree in its variation from the black body, remains to be determined.

In passing it is interesting to note that the experiment described above presupposes a certain relation among the α's which would seem to point to a constancy in α in moderate changes of temperature. This is in contradiction to the results of the investigation by Coblentz and should hence receive further consideration.

V. RÉSUMÉ OF THE NEW PHOTOMETRIC METHODS AND RESULTS.

In summarizing the two photometric methods which have been discussed at some length there are two features to be emphasized: (1) the viewpoint which constituted the basis of the measurements, and (2) the extreme simplicity of the methods employed. The viewpoint consisted in comparing the radiating properties of various substances when brought to the same distribution of energy in the visible region of the spectrum. The method employed to secure this condition consisted merely in bringing the two sources to a match in color by the use of an ordinary Lummer–Brodhun contrast photometer. The two methods used in the study of the radiating properties under this condition consisted merely in determining the lumens per watt, and the ratio of the percentage change in watts. Except, therefore, for the work on the electrically heated black body as a reference point, and for the check measurements made with spectrophotometer and infra-red spectrometer, the entire investigation could be carried out with an ordinary photometer and adequate ammeters and volt-meters.

The viewpoint lying at the basis of the measurements is at the same time quite old and yet distinctly new. One of the oldest methods of pyrometry depended upon the color of the light as determined by eye observations without reference, however, to any standard; but this old method could lay claim neither to any high degree of accuracy, nor to any theoretical application to the study of the radiating properties of matter. Morris, Stroude and Ellis,[21] 1907, made the blanket assumption that as a first approximation all filaments could be considered as of the same temperature when operating at the same color, but in the discussion apparently no special significance is attached to this point. Again in 1907 Leder,[22] in studying the Hefner and osmium filament lamps, determined the temperature of the black body for equal distribution of energy in the visible spectrum, but instead of realizing the full significance of his results he argued an extremely high operating temperature of the osmium apparently on the ground of the low emissivity of all metals as compared with a black body. It is thus true that the black body temperature, as determined in the ordinary way with the customary optical pyrometers, is lower than the true temperature of the

body, but the equation of absolute emissivity does not enter when the method of comparison is by color match. In fact, the true temperature of the selective body is quite probably lower, rather than higher than the temperature of the black body when at a color match, in this way affording an upper limit of temperature, just as the ordinary methods of optical pyrometry afford a lower limit of the true temperature.

The results obtained by the application of the photometric methods show very interesting facts. All metals studied are selective, and, as would seem probable from the results, selective in the same way, *i.e.*, in favor of the shorter wave-lengths. All three of the metals, tantalum, tungsten and osmium, appear to be more selective than platinum, the osmium deviating farthest. On the basis of one assumption, which, though probable, is not necessarily true, the conclusion results that when at the same true temperature osmium is at least 40 or 50 per cent. more efficient as a luminous radiator than untreated carbon.

The limitation to the experimental methods as described thus far is found in the restriction to the study of substances which can be heated in a vacuum by the passage of an electric current. By the use of a surface bolometer (a special form of which is now being constructed through the courtesy of the Leeds & Northrup Co.) to measure directly the radiant energy, rather than depending upon the electrical power supplied, substantially the same general method may be employed in a more general way. It is hoped thus with some modifications to extend the measurements to a study of flames, gas mantles, and other forms of luminous sources.

REFERENCES.

[1] Charpentier, Sur les Phénomènes Rétiniens, Rapports Congrès International de Physique, vol. iii, 523, Paris, 1900.
[2] Koenig, Gesammelte Abbandlungen zur Physiologischen Optik, Leipzig, 1903, 144, *et. seq.*
[3] Koenig, *Loc. cit.*
[4] Lummer and Kurlbaum, Verh. d. Phys. Ges. zu. Berlin, vol. xvii, 106, 1898.
[5] Physical Review, vol. xxvii, 521, 1908.
[6] Hyde, Cady and Middlekauff, Trans. Ill. Eng. Soc., vol. iv, 334, 1909; Electrical World, vol. liii, 439, Feb. 1909; Ill. Eng., London, vol. ii, 241, 335, 1909.
[7] Waidner and Burgess, Preliminary Measurements on Temperature and Selective Radiation of Incandescent Lamps, Bulletin Bur. of Stds., vol. ii, 319, 1906. See also Holborn and Kurlbaum, Ann. der Physik, Ser. 4, vol. x, 236, 1903.
[8] Paschen, Ann. der Physik, Ser. 3, vol. lviii, 455, 1896.

[9] Coblentz, Bull. Bur. of Stds., vol. v, 339, 1909. See also Elec. World, vol. lii, 1345, 1908.
[10] See Aschkinass, Ann. d. Physik., Ser. 4, vol. xvii, 960, 1905.
[11] This conclusion has been corroborated by Drysdale (see London Illuminating Engineer, vol. i, 27 *et seq.*, 1908) and Fery and Cheneveau (see Bull. de la Societé Internat. des Electriciens, Series 2, vol. ix, 655, 1909), while Lux (see London Illuminating Engineer, vol. i, 98, 1908) has found quite appreciable differences between the energy in-put and that radiated.
[12] For a description of the type of electrically heated black body used, see Waidner and Burgess, Bull. Bur. of Stds., vol. i, 189, 1905.
[13] See also Lummer and Pringsheim "Ziele der Leuchttechnik," Lummer, R. Oldenbourg, München and Berlin, 1903, p. 99. (From the data of Lummer and Pringsheim, the value of 3.65 is obtained by interpolation, which agrees very well with that given in the table.)
[14] Practically this same method was employed by Eisler several years ago. See E.T.Z., vol. xxv, 188 and 443, 1904.
[15] See *idem* for probable reason.
[16] Phys. Rev., vol. xiii, 65, 1901.
[17] Phys. Rev., vol. xiii, 345, 1901.
[18] Phys. Rev., vol. xvi, 123, 1903.
[19] *Loc. cit.*
[20] *Loc. cit.*
[21] J. T. Morris, F. Stroude and R. M. Ellis, Electrician, vol. lix, 584, 1907.
[22] F. Leder, Ann. d. Physik., Ser. 4, vol. xxiv, 305, 1907.

Radio-Activity of Potassium Salts. J. C. MCLEANAN. (*Phys. Review*, 1909, 29.)—The radio-activity of potassium salts was investigated by the method in which one vessel is placed within, and insulated from, a second and the electrical charge which the insulated body or vessel more or less rapidly acquires is then observed. Preliminary experiments were made on the charging action of polonium, and that of the secondary rays excited in aluminum by the R-rays from radium; the charges acquired by uranium salts at low pressures were also observed. In the case of potassium salts the results show that in high vacua both potassium nitrate and potassium sulphate emit an excess of charged particles of the β-type. The effect observed was small in all cases and it required exceptional conditions to bring it into evidence. It was not found possible to decide whether any radiation of the α-type is emitted by the potassium salts or not.

Propagation of Flame by Coal-Dust in Mine Galleries. J. TAFFANEL. (*Comptes rendus*, 1909, 149.)—Tests made in the experimental mine galleries at Liévin show that when a gallery is partially blocked or when it exhibits a sharp bend, the violence of a coal-dust explosion undergoes considerable diminution. Further, when the partial stoppage of the gallery is effected by means of movable and incombustible materials, these are carried along by the gases preceding the explosive flame and exert a cooling action sufficient to prevent the further propagation of the combustion.

THE PHENOMENA OF FLOCCULATION AND DEFLOCCULATION

BY

E. E. FREE.

(*Presented at a Stated Meeting of the Section of Physics and Chemistry, held March* 10, 1910.)

(*Concluded from Vol. CLXIX, page 438.*)

THE EFFECT OF ORGANIC COLLOIDS ON SUSPENSIONS.

The other general class of bodies known to importantly influence flocculation is that which includes the organic colloids, typified by gelatin, dextrin, the albumins, etc. These have long been known to have a pronounced tendency to stabilize and prevent the flocculation of suspensions to which they are added. This is the commonest, and was for a long time the only, method of making and preserving the instable inorganic colloids. The various colloidal solutions of metals, colors, etc., which are now finding wide application in the arts and in medicine are almost all prepared and preserved in this way. This action is, however, more a passive than an active one. These bodies tend to keep apart, and suspended, particles already in a separate condition, but aggregates already existing in a suspension must be destroyed (by shaking or otherwise) in order to bring into play the stabilizing action. There is no evidence that these bodies (the colloids) have themselves any active tendency in breaking up aggregates or in decreasing the degree of flocculation. They are preventives of flocculation rather than deflocculators. Practically, of course, the result is the same. The shaking or stirring which usually accompanies the addition of the colloid to a suspension itself mechanically destroys a large proportion of the aggregates and the colloid then prevents the reflocculation which would otherwise take place.

It should be noted also that the colloids which show this stabilizing action belong exclusively to the fifth class of disperse systems as set forth in Table I. That is, they are liquid-particle

colloids (really very fine-grained emulsions), and consist of a suspension of very minute liquid particles in a liquid medium. The reason for the close limitation to this class of bodies will appear on examination of the mechanism of the action—in this case fairly well understood. In brief, what happens is that the particles of the original suspension are enveloped by a thin film of the colloidal material acting in accordance with the well-known surface tension laws in precisely the same way in which a drop of oil spreads itself out in a thin film on a water surface. This can obviously take place only when the colloidal particles are liquid and able to spread themselves out in thin films. It can also take place only when the relative values of the surface tensions demand it, and as these values vary for different substances, not all liquid-particle colloids can be expected to show the action in the same degree. Nor, indeed, do they. The stabilizing power of the various colloids varies greatly, and there are many such bodies which do not show it at all.

This leaves unexplained the reason why the surrounding film of foreign material should so effectively prevent flocculation, but the solution of this question must await a better knowledge of the causation of flocculation itself and the primary factors which influence it.

PRACTICAL BEARINGS OF FLOCCULATION.

In conclusion it may be well to indicate briefly some of the ways in which the phenomena we have been discussing are of practical importance in the laboratory and the factory. Lack of time forbids any detailed treatment, and indeed such treatment is hardly possible in the present state of knowledge. Certain empirical flocculators and deflocculators have been in use for years, but general principles have been lacking and are only now beginning to be discovered and applied.

The most obvious applications of the principles of flocculation are to the processes of precipitation, filtration, and the general handling of fine precipitates and of colloidal matters both technically and in the laboratory. For instance, an increase in the degree of flocculation will permit the collection by subsidence, or on a filter, of suspended matter which in its deflocculated state would be too slowly precipitated for one process and too fine-grained for the other. This is one reason why analysts

boil precipitates in order to collect them more easily,[13] and why in other cases they add solutions of ammonium nitrate, nitric acid, and other flocculating agents. Technical applications are found in the collection of lime sludges from caustic tanks, in the "salting out" of colloids and emulsions, etc. Many other important technical applications are found in the processes of water purification and clarification, but this is a science in itself and cannot be discussed here.

A second important line of application is in the manufacture of permanent suspensions, colloidal and otherwise, and the use of deflocculating agents (mainly organic colloids) for this purpose has grown to enormous proportions. The ordinary liquid India ink, for instance, is simply a suspension of very finely divided lamp-black preserved by the addition of both organic colloidal matter and an alkali (usually ammonia). The various suspensions and emulsions used in medicine are similarly prepared and preserved. Preparations of permanently suspended "colloidal" silver and iron are now in general use by physicians. The most brilliant application in this field is, however, the celebrated deflocculated graphite of Mr. Acheson. By very fine grinding and by the use of tannin and other colloidal bodies, with or without alkalies, Mr. Acheson some time ago succeeded in keeping graphite in practically permanent suspension in water. Later he accomplished the much more difficult feat of suspending it in oil, thus producing an exceedingly valuable lubricant which is having wide application.

A third series of phenomena in which flocculation effects are of great importance is that of the plasticity of clays. Here the desideratum is the minimum of flocculation, and potters have for years been using two expedients, both of which we have seen to act in this direction—lowering of temperature and the addition of organic colloids. The latter in particular is of very ancient application. Straw and similar refuse (all containing colloidal material) have been customarily added to worked clay since the beginnings of industry.

The fourth great line of application, and the last of which I shall speak, is in the biologic reactions of coagulation, agglu-

[13] Rise of temperature, as already noted, increases the degree of flocculation. The other reason for boiling is to obtain the increase of crystal size usually caused thereby.

tination, etc. These reactions are of high theoretical interest in connection with the mechanism of the vital processes, and are of great potential value to mankind. They are exceedingly complex, and, as yet, very little understood, but the best minds of the medical profession are being applied to their solution and light may be expected soon in this direction.

I have said nothing concerning the phenomena with which my own work in this field has been mainly concerned—flocculation in soils. These phenomena are so important agriculturally that they can hardly be left unnoticed, but as they include factors entirely foreign to the preceding discussion, I shall treat them separately in an appendix to this paper.

SUMMARY.

The present knowledge of flocculation phenomena, as outlined in this paper, may be roughly summarized as follows:

1. The phenomena of flocculation occur in "disperse" systems consisting of fine particles distributed through a medium and classifiable according to size of particle and to the physical state of the particle and the medium.

2. They are characteristic of these states of matter and not of any particular substance or substances.

3. Flocculation and deflocculation are but relative terms. The more exact concept is that of *degree of flocculation.*

4. This degree of flocculation is influenced by many factors of which the main are added substances of the following three classes: (1) Most acids and neutral salts which increase the degree of flocculation. (2) The stronger alkalies, which decrease the degree of flocculation. (3) Most organic (liquid-particle) colloids, which prevent increase in the degree of flocculation.

5. The action of salts, acids and alkalies is probably at least two-fold: (1) on the mutual interpenetration (solubility) of particle and medium; (2) on the electric charges on the surface of the particle.

6. The stabilizing action of organic colloids is due to the formation of thin films of the colloid substance about the suspended particles.

7. There are many applications of flocculation phenomena

to the handling of precipitates and suspensions, the preparation of permanent suspensions, the working of clay, certain biologic reactions, etc.

APPENDIX—FLOCCULATION IN SOILS.[14]

It is obvious that the kinds of flocculation phenomena discussed in the previous pages cannot be the main ones which occur in the soil. There is nothing to correspond either to the suspended particles or to the medium of suspension. The soil contains not only solids and liquids but gases as well. The phenomena at the gas-liquid surfaces must be taken into account, and indeed the surface tensions at these surfaces are really the controlling forces in soil flocculation.

The mechanism is as follows: In a moist, but unsaturated soil, the water exists mainly in the form of thin films about the soil particles. At the points where the solid particles touch each other these surrounding water films are also in contact, and when the soil is sufficiently moist the water-film system is continuous throughout its mass. The existence of these films was early recognized and their importance in controlling the movement of water through soils has long been appreciated. Only recently, however, has it been discovered that these films are of paramount importance in controlling the *structure* of the soil, and this is what mainly concerns us here.

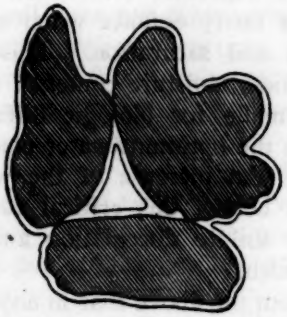
The conditions are shown in Fig. 6, which represents in cross-section three soil particles with their surrounding water films. At each point of contact the water films fuse, filling the wedge-shaped space between the particles and forming a curved surface such as represented diagramatically in Fig. 7. From the well-known surface tension laws it is obvious that there will be a force tending to pull the sides of the wedge together, or, in the case of soil grains, to hold them together at each point of contact. This force at the fusion surfaces of the water films is the main cause of the formation and preser-

[14] The facts and explanations here given are taken largely from Bulletin 50 of the Bureau of Soils, U. S. Dept. of Agriculture; "Moisture Content and Physical Condition of Soils," by F. K. Cameron and F. E. Gallagher (1908).

vation of aggregates in the soil.[15] Without it there would be no flocculation.

The absolute values of these forces between the grains depend on the curvature of the water surface and it is obvious that this curvature will vary as the water surface retreats toward

FIG. 6.



Cross-section of soil grains showing surrounding water films.

or advances from the point of solid contact—that is, as the water films generally decrease or increase in thickness. Such changes in the water films are brought about by changes in the water content of the soil, and this is the reason for the great influence of moisture content upon the degree of soil flocculation. If a soil be so dry that the water films which do exist

FIG. 7.

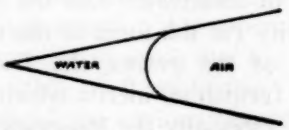


Diagram of water-film surface in a wedge-shaped space.

are not generally in contact with each other, the surface tension forces will not exist and the soil structure will be controlled by gravity alone. If, on the other hand, the soil be saturated or nearly so, the interstitial spaces will be entirely filled with water, the gas-liquid surfaces and their tensions will disappear,

[15] The chemically cemented aggregates which occur in some few soils are, of course, excluded from consideration.

and the structure of the soil will again be controlled in the main by gravity. It is apparent, therefore, that the activity of the water films, and therefore the degree of aggregation or flocculation will be greatest at some intermediate water content. It has indeed been discovered experimentally (and before this theory was developed) that the physical properties of a soil which depend upon its degree of flocculation [16] are at a maximum (or minimum) at a fairly definite water content intermediate between air-dryness and saturation. This water content has been called the "critical moisture content" and has been found, when allowance is made for biologic differences, to be practically identical with the optimum water content for the growth of ordinary plants. An increase of the water present above, or a decrease of it below, this critical content, decreases the susceptibility of the soil to flocculation and hence its capacity to be put in good tilth.

It is apparent from the above that in any particular soil there must be for each definite water content a corresponding structure or degree of aggregation which is normal for that water content. It does not follow, however, that the soil in the field always possesses the structure which is normal to it and for the water content which it happens at that moment to hold. Were the soil particles perfectly free to move among themselves, the soil mass would no doubt always possess the structure theoretically required by its water content, and changes in water content would be followed immediately by the corresponding changes in structure. But the soil particles are not free to move. Gravity (in the form of the weight of superposed soil), the adhesion of the grains, the friction between them, and similar factors, furnish an inertia which strongly resists any change of structure, especially the loosening which must accompany an increase in the degree of flocculation. In general, therefore, the actual structure of a soil at any particular moment is not that corresponding to its water content, but rather that which has resulted from the action of its various past water contents working against the inertial factors and complicated by various extraneous factors of which the main are the operations of agriculture.

[16] The resistance to penetration, the apparent specific gravity, etc.

But although a soil does not in itself respond readily to changing water content, if it be artificially stirred, as *e.g.*, by plowing, the structure which it will take on is largely determined by its water content. Hence the importance of conducting cultural operations when the soil is neither too dry nor too wet—when, in scientific phrase, its water content is at or near the "critical" value. The existence of this "critical" (or optimum) water content in a soil does not mean necessarily that the soil possesses the optimum physical structure, but does mean that it has then and then only the capacity to take and retain that structure under the action of cultural processes.

The actual amount of water which corresponds to the maximum of flocculation (or better, capacity for flocculation) varies widely in different soil types. The values which have so far been obtained range from 30 to 40 per cent. (by weight) for clays to 3 and 4 per cent. for sands. Ordinary loams run from 10 to 20 per cent.

Though for most normal soils the surface tension forces as thus outlined are the strongest of those influencing flocculation, yet effects similar to those discussed in the first part of this paper are sometimes of importance, especially where the soil particles are very fine, as in clays. In these soils the interstitial spaces are so small as to be comparable in size with the minimum thickness of a water film capable of exerting mechanical forces. Consequently, when there is enough water present to provide surrounding films for all of the particles, the interstitial spaces are themselves nearly filled with water and the gas-liquid surfaces have largely disappeared. We approach here the case of suspension of solid particles in water and the laws of flocculation in such systems are fairly well applicable. The reactions, the so-called "colloidal clay," the various phenomena of the baking, crusting, etc., of clay soils show many similarities to the phenomena of flocculation in suspensions, and it is probable that still more correspondences and analogies will appear as this field is more fully studied.

Though these phenomena (actions analogous to those of suspension-flocculation) are observable only in clays, it is probable that they are not confined thereto. There is indeed every reason to believe that they are duplicated in kind in all soils *at the liquid-solid surfaces*. In most soils, however, these effects are

entirely masked by the much stronger forces which act at the gas-liquid surface. Only when this surface is destroyed by saturation do the former effects become apparent.

All this concerns the action of water alone as an agent of soil flocculation. It remains to notice briefly the effects of substances dissolved in the water in modifying its flocculating action. The effects of such substances can manifestly be two-fold: (1) those on the flocculating forces at the liquid-solid surface; and (2) those on the gas-liquid surface tension of the water. It was long ago suggested that these effects, especially the second, are important items in the action of fertilizer salts on the soil, but there is an almost total lack of definite data, and accurate analysis of the phenomena is not possible at present. Practically, there are only two substances, the effects of which on soil flocculation are sufficiently clear and striking to have received general recognition: lime, which is a strong flocculator; and sodium carbonate ("black alkali") which has the opposite tendency. In neither of these cases is the mechanism of the action fully understood, but it is probable that both are in the main effects analogous to the phenomena occurring in suspensions, and concern only in minor degree the gas-liquid surface tension. This seems especially probable from the fact that these actions are very clearly shown by clays and hardly noticeable at all in sandy soils. We have already seen that the flocculation of soils of the former class is much more nearly analogous to that of suspensions.

BIBLIOGRAPHY.*

I. Suspension and Flocculation in General.

Barus, Carl.
The subsidence of fine solid particles in liquids. U. S. Geol. Surv., Bull. **36**: (1886), 51 p.
The subsidence of fine solid particles in liquids. Amer. Jour. Sci. (3) **37**: 122-129 (1889).

Barus, Carl, and Schneider, E. A.
Über die Natur der kolloïdalen Lösungen. Zs. phys. Chem. **8**: 278-297 (1891).

Bechhold, H.
Die Ausflockung von Suspensionen bzw. Kolloiden und die Bakterienagglutination. Zs. phys. Chem. **48**: 385-423 (1904).

Billitzer, Jean.
Versuch einer Theorie der Mechanischen und colloidalen Suspensionen. Sitzungsber. Akad. Wiss., Wien., Abt. 2, **111**: 1393-1432 (1902).

* This bibliography gives only a few of the more important titles. It makes no pretense of completeness.

Zur Theorie der Suspensionen und der elektrischen Doppelschichte, Ib. **112**: 1098-1106 (1903).
Eine Theorie der Kolloide und Suspensionen. Zs. phys. Chem. **45**: 307-330 (1903).

Bodlaender, G.
Versuche über Suspensionen. Neues Jahrb. Min. **1893**: II; 147-168.

Brewer, William H.
On the subsidence of particles in liquids. Mem. National Acad. Sci. **2**: 163-175 (1884).
On the suspension and sedimentation of clays. Amer. Jour. Sci. (3) **29**: 1-5 (1885).

Durham, William.
Suspension of clay in water. Chem. News **30**: 57 (1874).
Suspensions of clay in water. Proc. Edinb. Phys. Soc. **4**: 46-50 (1878).
Suspension, solution and chemical combination. Proc. Roy. Soc. Edinb. **9**: 537-541 (1878), and Chem. News **37**: 47-48 (1878).

Ehrenberg, Paul.
Die Beziehung der Kolloidforschung zur Agrikulturchemie. Zs. Chem. Ind. Kolloide **3**: 193-206 (1908).

Fickendey, E.
Notiz über Schutzwirkung von Kolloiden auf Tonsuspensionen und natürliche Tonböden. Jour. Landw. **54**: 343-348 (1906).

Freundlich, Herbert.
Über das Ausfällen kolloidaler Lösungen durch Elektrolyte. Zs. phys. Chem. **44**: 129-160 (1903).
Kapillarchemie. Leipzig, 1909, 536 p.

Hall, A. D., and Morison, C. G. T.
The flocculation of turbid liquids by salts. Jour. Agric. Sci. **2**: 244-256 (1907).

Hardy, W. B.
A preliminary investigation of the conditions which determine the stability of irreversible hydrosols. Proc. Roy. Soc. London **66**: 110-125 (1899), and Zs. phys. Chem. **33**: 385-400 (1900).

Hermann, Hugo.
Über das Absetzen von Tonemulsionen. Zs. anorg. Chem. **53**: 413-418 (1907).

Hilgard, E. W.
On the flocculation of particles, and its physical and technical bearings. Amer. Jour. Sci. (3) **17**: 205-214 (1879).

Holland, P.
See Reade, T. Mellard.

Hunt, T. Sterry.
The deposition of clays. Proc. Boston Soc. Nat. Hist. **16**: 302-304 (1874).

Joly, J.
Preliminary note on the inner mechanism of sedimentation. Sci. Proc. Roy. Dublin Soc. (n. s.) **9**: 325-332 (1900).
Some sedimentation experiments and theories. Sci. Trans. Roy. Dublin Soc. (2) **7**: 391-402 (1902).

Jordis, Eduard.
Kritik der Grundlagen einer Theorie der Kolloide. Zs. Chem. Ind. Kolloide **2**: 361-367; **3**: 13-26, 153-166 (1908).

Mayer, Adolf.
Über die Einwirkung von Salzlösungen auf die Absetzungsverhältnisse thoniger Erden. Forsch. Geb. Agr.-Phys. **2**: 251-273 (1879).

Michaelis, Leonor, and Pinkussohn, Ludwig.
Zur Theorie der Kolloidumhullung. Biochem. Zs. **2**: 251-263 (1906).

Morison, C. G. T.
See Hall, A. D.

Ostwald, Wolfgang.
Grundriss der Kolloidchemie. Dresden, 1909, 509 p.
Perrin, Jean.
Mécanisme de l'électrisation de contact et solutions colloidales. Jour. chim. phys. **2**: 607-665 (1904); **(3)** 51-110 (1905).
Pinkussohn, Ludwig.
See Michaelis, Leonor.
Quincke, G.
Über die Bewegung und Anordnung kleiner Teilchen, welche in Flüssigkeiten schweben. Vehr. Ges. Naturf. und Aerzte **1898**: 26-29.
Über die Klarung trüber Lösungen. Verh. Heidelb. naturh.-med. Ver. (n. s.) **7**: 97-104 (1901), and Ann. Phys. (Drude), (4) **7**: 57-96 (1902).
The clearing of turbid solutions and the movement of small suspended particles by the influence of light. Report Brit. Assoc. Adv. Sci. **1901**: 60-64.
Ramsay, William.
On the influence of various substances in accelerating the precipitation of clay suspended in water. Quart. Jour. Geol. Soc. **32**: 129-133 (1876).
Reade, T. Mellard, and Holland, P.
Sands and sediments. Proc. Liverpool Geol. Soc. **10**: 48-78 (1905).
Reinders, G.
Beitrag zur Kenntniss der Einwirkung des Meerwassers auf den Boden. Landw. Versuchsstat. **19**: 190-214 (1876).
Scheerer, Theodor.
Einige Beobachtungen über das Absetzen aufgesschwemmter pulverförmiger Körper. Ann. Phys. (Poggendorff), (2) **82**: 419-429 (1851).
Schloesing, Ch.
Sur la précipitation des limons par des solutions salines tres-étendues. Comptes rendus **70**: 1345-1348 (1870).
Schneider, E. A.
See Barus, Carl.
Schulze, Franz.
Die Sedimentär-Erscheinungen und ihr Zusammenhang mit verwandten physikalischen Verhältnissen. Ann. Phys. (Poggendorff), (2) **129**: 366-383 (1866).
Schulze, Hans.
Schwefelarsen in wässeriger Lösung. Jour. prakt. Chem. (2) **25**: 431-452 (1882).
Antimontrisulfid in wässeriger Lösung. Ib. (2) **27**: 320-332 (1883).
Skey, William.
Coagulation and precipitation of clay by neutral salts generally. Chem. News **17**: 160 (1868).
Spring, W.
Sur la flocculation des milieux troubles. Bull. Acad. Roy. Belg., Classe de Sci., **1900**: 483-520, and Rec. trav. chim. Pays-Bas. **19**: 204-236 (1900).
Stuntz, Chauncey R.
Clarification of the public water supply of Cincinnati. Jour. Cin. Soc. Nat. Hist. **9**: 20-35 (1886).
Waldie, D.
On the muddy water of the Hugli during the rainy season with reference to its purification and to the Calcutta water supply. Jour. Asiat. Soc. Bengal **42**, II; 210-226 (1873).
Weimann, P. P. von.
Zur Lehre von den Zuständen der Materie. Zs. Chem. Ind. Kolloide **2**: 199-208, 230-237, 275-284, 301-307, 326-335; **2**: Suppl.-h.

II; LII-LXI; 3: 282-304; 4: 27-37, 123-139, 198-202, 252-265, 315-317; 5: 62-68, 117-120, 150-159, 212-221 (1907-9).

Zsigmondy, Richard.
Zur Erkenntnis der Kolloide. Jena, 1905, 185 p.

II. The Mechanics of Suspension.

Boggio, Tommaso.
Integrazione dell'equazione funzionale che regge la caduta di una sfera in un liquido viscoso. Rendiconti Accad. Lincei (5) 16, II: 613-620 (1907).

Buller, A. H. Reginald.
The rate of fall of fungus spores in air. Nature 80: 186-187 (1909).

Cunningham, E.
On the velocity of steady fall of spherical particles through fluid medium. Proc. Roy. Soc. London (A) 83: 357-365 (1910).

Orsi, Giovanni.
Über die Flugfähigkeit des Staubes. Arch. für Hygiene 68: 22-53 (1908).

Ostwald, Wolfgang.
Zur Theorie der Schwebevorgänge sowie der specifischen Gewichtsbestimmungen schwebender Organismen. Arch. gesammte Physiol. 94: 251-272 (1903).

Perrin, Jean.
La loi de Stokes et le mouvement brownien. Comptes rendus 147: 475-476 (1908).

Picciati, Giuseppe.
Sul moto di una sfera in un liquido viscoso. Rendiconti Accad. Lincei (5) 16, I: 943-951 (1907).
Integrazione dell'equazione funzionale che regge la caduta di una sfera in un liquido viscoso. Ib. (5) 16, II: 45-50 (1907).

Thoulet, J.
Expériences relatives a la vitesse des courants d'eau ou d'air susceptibles de maintenir en suspension des grains minéraux. Ann. de Mines, Mémoires, (8) 5: 507-530 (1884).
De l'influence du vent dans le remplissage du lit de l'ocean. Comptes rendus 146: 1184-1186 (1908).

Uller, K.
Über den Verdrangungswiderstand fester Körper in Gasen und Flüssigkeiten. Ann. Phys. (Drude) 23: 179-196 (1907).

Zeleny, John, and McKeehan, L. W.
An experimental determination of the terminal velocity of fall of small spheres in air. Science (n. s.) 29: 469 (1909).
The terminal velocity of fall of small spheres in air. Nature 82: 158 (1909).

Bureau of Soils,
U. S. Department of Agriculture,
Washington, D. C.

THE HOPKINS GASOLENE-ENGINE DYNAMOMETER AND SPEEDOMETER.

BY

N. MONROE HOPKINS, Ph.D.,

WASHINGTON, D. C.

(*Stated Meeting held Wednesday, January* 19, 1910.)

[It is not ordinarily a simple operation to determine the power continuously delivered by an internal combustion engine. The apparatus here described is designed to reduce the operation to the simplicity of reading the horsepower from a dial and essentially consists of a current meter whose readings are proportional to the product of the speed of rotation and the temperature of the gases within the cylinder.]

THE following is a brief description of the experimental work undertaken at the laboratory of the writer in developing a dynamometer for indicating the working conditions existing in the cylinders of gas and gasolene motors. It occurred to the author of this paper that a thermocouple as evolved by Becquerel for measuring temperatures as existing in the various types of commercial furnaces for steel, porcelain, etc., would cast much light on certain important conditions which exist within the cylinders of internal combustion motors. A sensitive thermocouple, it was evident, would show temperature, indicate immediately the failure of any cylinder to fire in the case of multiple cylinder motors, and more important, such a thermocouple would show carburetor adjustment. It is well known that the highest temperature in an engine cylinder is attained when just enough hydrocarbon vapor is drawn into the cylinder with just enough air, the oxygen from which completely converts the hydrocarbon vapor into its ultimate combustion products.

Not possessing a suitable automobile engine at the time of carrying out the initial experiments, one was borrowed for making the test and four improvised plugs carrying simple Becquerel thermocouples were constructed by the writer, in his Washington laboratory, and were connected to a specially designed milli-voltmeter attached to the dash of an automobile. Fortunately or unfortunately, the automobile belonged to a friend! On first cranking the motor the engine started off beautifully and an indication was at once shown upon the electrical

instrument, but the smooth and perfect operation of the motor was only momentary—violent pounding and bucking being soon apparent. In attempting to drive the car up the street, the engine was nearly shaken to pieces because of violent pre-ignition, discovered to be due to the hot thermocouple protruding into the

FIG. 1.

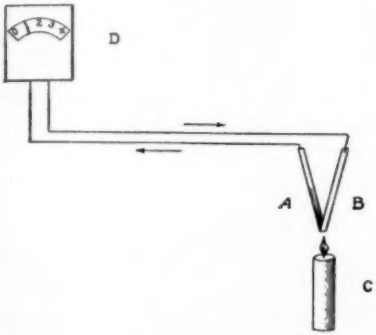
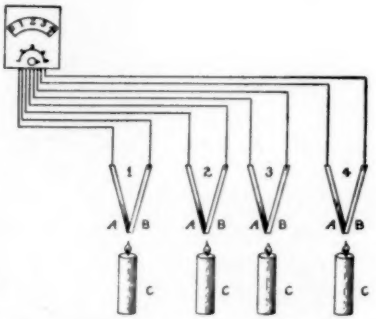


FIG. 2.



cylinders. Since that time, constant experimental work has been in progress with the view of developing a thermocouple of successful operation within gasolene-engine cylinders.

Fig. 1 shows the fundamental principle as evolved by Becquerel, illustrated by the candle flame, thermocouple and voltmeter.

TABLE I.

GAS MIXTURE	GAUGE PRESSURE	TEMPERATURE, F.
1 gas to 13 air	52	1,916 degrees
1 gas to 11 air	63	2,309 degrees
1 gas to 9 air	69	2,522 degrees
1 gas to 7 air	89	3,236 degrees
1 gas to 5 air	96	3,484 degrees
1 gas to 4 air	80	2,111 degrees

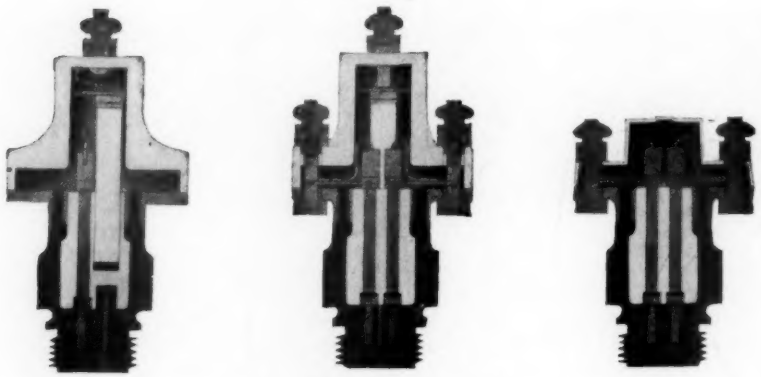
Fig. 2 shows an elaboration of Becquerel's pyrometer—applied with disastrous effects to a four-cylinder automobile! Table I shows in column one gas mixture, gauge pressure in column two, and temperature in column three. It is evident from study of this table that a thermocouple, if it could be made to operate successfully in the several cylinders of a cylinder motor, would prove of inestimable value in showing best gas mixture or carburetor adjustment and it will be noted that when a mixture of 1 gas to 5 air is admitted the maximum gauge pressure,

namely 96 pounds, is attained, also the maximum temperature of 3484 degrees.

As pointed out, ordinary thermocouples as evolved by Becquerel, shown in the foregoing diagrams and used for general temperature measurement in the arts and sciences, would never "live" or operate under the peculiar chemical conditions in a gasolene-engine cylinder. Not only because they would become so heated as to pre-ignite the charge and cause the engine to buck, hitch or back-fire, as already described, but in addition would become brittle and drop apart through either oxidation or the absorption of carbon after a short period of use.

Actual temperature measurements by means of thermo-

FIG 3.

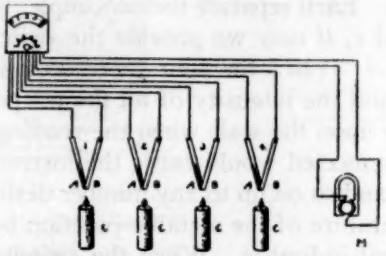


couples or thermometers of any kind could not be made in gasolene-engine cylinders. As a result of the experimental work conducted it has been made possible, by means of especially designed and constructed thermocouples, the limbs of which are enveloped in massive metal tubes, to give an *index* of the temperature in a gasolene-engine cylinder without attempting actually to measure it.

The dynamometer as finally constructed faithfully and continuously shows by these modified temperature readings the working conditions of gasolene-engine cylinders. Fig 3 shows the cross-section of some of the special thermocouples enveloped by heavy metal tubes, insulated by porcelain bushing, and made gas-tight within a steel-threaded shell for screwing into an engine cylinder. Such thermocouples made from even base metals and

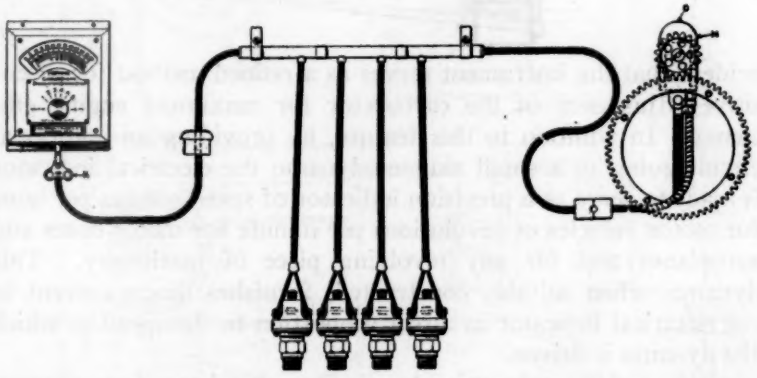
protected by metal tubes (providing an adequate thermal circuit is formed) will indicate for practically an unlimited period of time without pre-ignition or back-fire and without undergoing molecular changes, oxidation or reduction.

FIG. 4



By using specially constructed spark plugs carrying thermocouple wires with a heat conducting tube around each limb of the thermocouple, the heat from the tip of the same is carried away at a predetermined rate. All thermocouples may be easily calibrated to read alike by carefully adjusting their lengths which protrude beyond the end of the copper tube. They are then

FIG. 5.

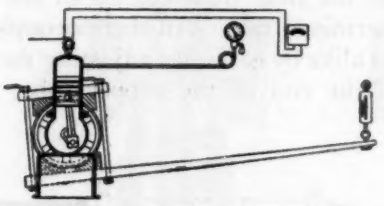


soldered in the oxyhydrogen blow-pipe flame when all the thermocouples become interchangeable and give the same electromotive force.

An exceedingly sensitive, satisfactory and practical instrument has been constructed upon this principle, that is, of making a thermocouple by virtue of its construction and production, to

maintain itself below the point of pre-ignition in a gas or gasolene-engine cylinder. In Fig. 2 it will be observed that the electrical indicator is provided with a switch by the turning of which it may be connected *selectively* to thermocouple No. 1, No. 2, No. 3, or No. 4, enabling one to determine if the four temperatures are of even intensity. Each separate thermocouple, for example, will give a reading of 1, if now we provide the switch with an additional contact "*A*" (all) the four thermocouples may be connected in *series* and the intensity of all the temperatures be indicated *collectively* upon the scale when the reading will be 4. Six thermocouples connected would cause the instrument to indicate 6 scale divisions and so on up to any number desired. Any variation in the temperature of the metallic junction becomes apparent upon the electrical indicator. When the switch is on the "*A*" contact and all the thermocouples are connected in series, it is

FIG. 6.



evident that the instrument serves as a refined method for a sensitive adjustment of the carburetor for maximum engine efficiency. In addition to this feature, by providing an additional circuit going to a small magnetodynamo the electrical indicator is made to serve as a precision indicator of speed—miles per hour for motor vehicles or revolutions per minute for motor boats and aeroplanes and for any revolving piece of machinery. This dynamo, when suitably constructed, furnishes direct current to the electrical indicator in direct proportion to the speed at which the dynamo is driven.

Fig. 4 will make this clear. Here we have four thermocouples as shown before but with the additional circuit at the right of the diagram connected with the small magnetodynamo "*M*" and the additional switch contact marked "*S*" (speed) on the face of the electrical indicator. If the magnetodynamo is now geared to the left front wheel of an automobile or the shaft of a motor boat or aeroplane, the indicating instrument may be

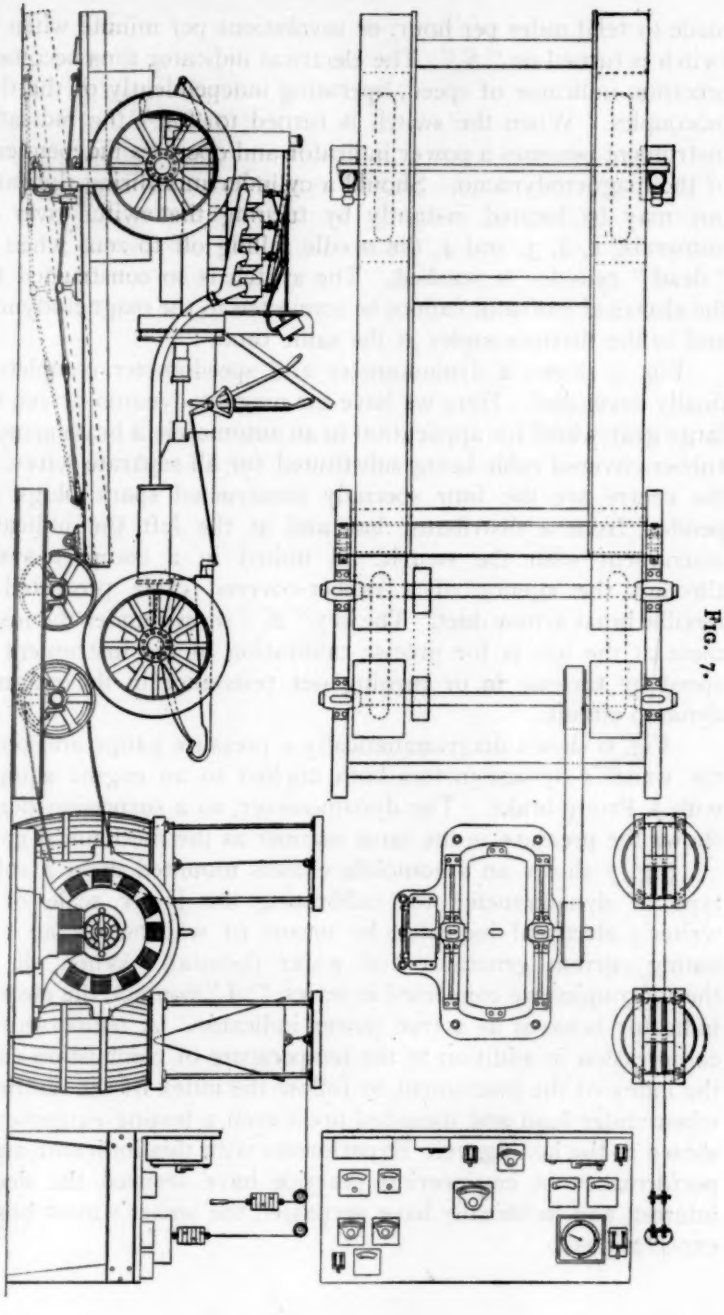


FIG. 7.

made to read miles per hour, or revolutions per minute when the switch is turned on "*S*." The electrical indicator thus becomes a precision indicator of speed, operating independently of the thermocouples. When the switch is turned to "*A*" the indicating instrument becomes a power indicator and operates independently of the magnetodynamo. Should a cylinder miss firing the faulty one may be located instantly by turning the switch over the numerals, 1, 2, 3, and 4, the needle falling off to zero when the "dead" cylinder is reached. The switch is so constructed that the electrical indicator cannot be connected to the magnetodynamo and to the thermocouples at the same time.

Fig. 5 shows a dynamometer and speedometer complete as finally developed. Here we have the magnetodynamo driven by a large gear-wheel for application to an automobile, a brass armored rubber-covered cable being substituted for all separate wires. In the centre are the four specially constructed spark plugs suspended from a distributor bar and at the left the indicating instrument with the switch, all united in a compact system through the agency of a rubber-covered cable protected by flexible brass armor duct. The key "*K*" shown under the instrument at the left is for precise calibration of the instrument for speed by turning in or turning out resistance in the magnetodynamo circuit.

Fig. 6 shows diagrammatically a pressure gauge and one of the writer's dynamometers both applied to an engine equipped with a Prony brake. The dynamometer, to a surprising degree, shows the pressure in the same manner as the mechanical gauge.

Fig. 7 shows an automobile chassis mounted upon a rolling type of dynamometer for calibrating the lower scale of the writer's electrical indicator by means of wattmeters, an alternating current generator and water rheostat. When all four thermocouples are connected in series, "*A*" contact, the electrical indicator behaves as a true power indicator. A temperature of compression in addition to the temperature of combustion causes the index of the instrument to follow the index of the wattmeter when under load and mounted upon such a testing equipment as shown in the last figure. Experiments with this indicator and its performance in engineering practice have secured the deepest interest, and technically have surpassed the writer's most hopeful expectations.

HARRY WALKER JAYNE, PH.D.

IN MEMORIAM.

Harry Walker Jayne, Ph.D.

By the death of Dr. Harry Walker Jayne at his home in Elkins Park on Monday, March 7th, 1910, in the fifty-third year of his age, a prominent place was made vacant, both among the leading members of the Franklin Institute and in the foremost rank of chemists in America. A close student of the chemistry of the coal-tar products, Dr. Jayne combined with the temperament of a genial personality the qualities of an accomplished technologist, a lucid writer and lecturer and of a practical and successful business man. His contributions to the literature of his specialty, published in the Proceedings of various scientific assemblies at home and abroad, in the JOURNAL OF THE FRANKLIN INSTITUTE and in other scientific periodicals, gained for him a recognized place as an authority on the technology of coal-tar and its innumerable products. Especially notable among Dr. Jayne's writings is his paper on "The Coal-Tar Industry in the United States" published in the Report of the Fifth International Congress of Applied Chemistry, Berlin, 1904, and that on "Determination of Water in Tar" in the *Journal of American Chemical Society*, vol. xiv, 1903. His library of chemical literature is reputed as among the most extensive private collections of this kind on either side of the Atlantic and embraces publications in all modern languages.

Dr. Jayne was born in Philadelphia June 16, 1857, son of the late David W. and Ellen F. Jayne, and grandson of Dr. David Jayne, the originator of the proprietary medicine known by his name. His education was begun in private schools in this city and was continued in the University of Pennsylvania, where he entered as a special student in the Junior Class in 1873 and remained until June, 1875. He then proceeded to Europe, where he spent a year at the University of Heidelberg, two years in Paris at the Sorbonne and the École de Médecine and two years at the University of Strasburg, obtaining from the last named institution the degree of Ph.D. in 1883. Returning home in that year, he soon thereafter established himself in the Frankfort district of Philadelphia as a manufacturer of fine chemicals and ultimately developed the business in the direction of the coal-tar products. In this specialty, the undertaking grew to large proportions and in 1896 was taken over by the Barrett Mfg. Co., of which concern Dr. Jayne continued as the managing director. He was a trustee of the estate of his noted grandfather and a co-manager with his brother, Mr. H. LaBarre Jayne, of the business of Dr. D. Jayne & Son. He is survived by his widow, born Florence N. Adams, of this city, and by three sons, David W., Chas. A., and Harry W. Jayne, Jr.

Besides his active connection with the Franklin Institute, Dr. Jayne was a member of the American Institute of Chemical Engineers, the American Chemical Society, the English Society of Chemical Industries, the Société Chimique of Paris, the Deutsche Chemische Gesellschaft, Berlin, the En-

gineers' Club of Philadelphia, and the Geographical Society of Philadelphia.

Dr. Jayne's membership of the Franklin Institute dates from September, 1874, when he was still a minor, and continued until his untimely death. In 1891 he was elected a member of the Board of Managers of the Institute and collaborated in that capacity with all the zest of his earnest nature. In May, 1903, he was appointed Chairman of the Committee on Publications in succession to the late Theodore D. Rand, and notwithstanding that his health became impaired as much as five years ago and gradually gave way increasingly, he continued his activity in that position until within barely over a year ago, when his failing strength prevented him from longer giving it his customary close attention.

Dr. Jayne was a notable example of devotion to duty and of efficiency in its performance, a man who fulfilled with precision and in detail whatever task was undertaken by him. Though his years fell all too short of the allotted span, they bore all the fruitage of a life well spent in study, service and accomplishment.

LOUIS EDWARD LEVY.

BOOK NOTICES.

PENROSE'S PICTORIAL ANNUAL. The Process Year Book. Edited by William Gamble. Volume XV, 1909–10. New York, Tennant and Ward. Contains 200 pages, illustrations, plates, 8vo. Price in cloth, $2.50.

The current issue of this well-known annual contains the usual amount of interesting information for the process worker. Sixty-nine articles, by contributors from all parts of the world, comprise the reading matter, numerous full-page specimens of two-, three-, four- and five-color prints are shown, and innumerable half-tones are distributed throughout the text. A photograph serves as frontispiece and one specimen of steel-plate engraving is included. The presswork is done with the usual care and the binding is uniform with previous volumes. R.

DER GRAPHIT. Eine technische Monographie von Ingenieur A. Haenig. 224 pages, illustrations, 12mo. Wien & Leipzig, A. Hartleben, 1910. Chemisch-technische Bibliothek, Band 323. Price, in paper, four marks.

As the literature on the subject of graphite is somewhat limited, those who are interested will undoubtedly find the present work useful. It contains in its 200 odd pages a review of the history of graphite; its properties and formation and the origin of the graphite deposits. Extraction, preparation and purification are followed by several chapters on its applications. The manufacture of lead-pencils is described and considerable attention is given to crucible making. The statistics of the subject are not overlooked, eleven pages being devoted to the world's production. The work closes with a chapter on artificial graphite. R.

FRANKLIN INSTITUTE

(*Proceedings of the Stated Meeting, held Wednesday, June* 15, 1910.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 15, 1910.

President WALTON CLARK *in the Chair.*

Present, 211 members and visitors.

Additions to membership since last report, 5.

The subject of the evening was presented by Mr. F. H. Stewart assisted by Mr. Max Milligan, the former gentleman presenting a brief outline of the history and development of picture projection. The most recent type of moving picture machine as made by the Edison Manufacturing Company was shown, and Mr. Milligan described the various films as they were projected on the screen. At the close of the demonstration a vote of thanks was tendered to the speakers and on the motion of Mr. Levy the subject was referred to the Committee on Science and the Arts for consideration. Adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS

(*Proceedings of the Stated Meeting, held Wednesday, June* 1, 1910.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 1, 1910.

MR. THOMAS SPENCER *in the Chair.*

The following report was presented for final action:

(No. 2463.) Murray's Safety Devices and Protective Appliances for Interior Electric Lighting. (Adopted, Longstreth Award.)

For first reading:

(No. 2421.) Wetherill's Instruments to Aid Navigation. (Advisory, Adopted.)

(No. 2481.) The Moore Light.

(No. 2491.) Deloe's Door Controller. (Advisory, Adopted.)

(No. 2496.) Branch's Asbesto Gleam Shades.

R. B. OWENS,
Secretary.

SECTIONS

Mechanical and Engineering Section.—A meeting of the Section was held on Thursday evening April 21 at eight o'clock; present, eighty members and visitors. In the absence of the Chairman, Dr. E. Goldsmith opened the meeting. After reading of the minutes the Chairman introduced Mr. Lennart Akesson, Director of the Swiss Liquid Gas Works, Zurich, who presented a communication on Liquid Gas, its manufacture and uses. The speaker described the process of Liquid Gas manufacture invented by Linus Wolf, and illustrated the subject by means of lantern slides and portable gas apparatus. After a brief discussion, which followed the paper, a vote of thanks was tendered the speaker for his interesting communication and the invention was referred to the Committee on Science and the Arts for investigation and report. Adjourned.

ALFRED RIGLING,
Acting Secretary.

Electrical Section.—A meeting of the Section was held on Thursday evening, April 28, 1910, at eight o'clock; present, sixty-five members and visitors. The meeting was called to order by Mr. Thomas Spencer, Chairman of the Section. After the reading of the minutes the chairman introduced Dr. Morton G. Lloyd, Associate Physicist of the Bureau of Standards, Washington, D. C., who spoke on Magnetic Hysteresis. The speaker described the latest methods of measuring magnetic quality in general and in particular the losses which occur in iron and iron alloys when placed in alternating and rotary magnetic fields. The results clearly showed the great improvement made in recent years in the quality of magnetic material used by the manufacturer of electrical apparatus of to-day. The subject was illustrated by lantern slides and specimens of metals. A brief discussion followed in which Dr. E. F. Northrup, Prof. Carl Hering, Dr. R. B. Owens, Dr. Goldsmith, the Speaker and the Chairman participated.

The thanks of the meeting were extended to Dr. Lloyd for his interesting address and his paper was referred to the Committee on Publications. Adjourned.

ALFRED RIGLING,
Acting Secretary.

Section on Physics and Chemistry.—The stated meeting of the Section held in the Hall of the Institute on Thursday, May 5, 1910, at 8 P.M. with Dr. Goldsmith in the Chair; present, thirty-five members and visitors. The minutes of the previous meeting were read and approved.

Mr. James Wood Pogue, Treasurer of the United States Linen Flax Corporation, presented a communication upon "Flax Growing and Linen Manufacturing in the United States, Present and Future." With the aid

of lantern slides, the time consuming mode of preparation of linen fibre as practised in the Old World for four thousand years, was described. An account was given of the Roberts process for the manufacture of linen fibre from flax, which is based upon the following treatment: (1) Mechanical breaking or shredding of flax straw; (2) boiling the shredded fibre in an alkali bath; (3) washing with water; (4) treatment in an acid bath; (5) washing with water; (6) treatment in a soap bath; (7) washing with water. The fibre then is combed and spun in the usual way. In conclusion it was stated that linen manufacture may be carried out in the United States on a large scale. The communication was discussed.

The thanks of the meeting were tendered Mr. Pogue; the paper was referred to the committee on Publications and the invention to the Committee on Science and the Arts. The meeting then adjourned.

JOSEPH S. HEPBURN,
Secretary.

Section of Physics and Chemistry.—The stated meeting of the Section on Thursday evening May 12, at eight o'clock, with Dr. Robert H. Bradbury, president of the Section, in the Chair; present, forty-five members and visitors.

Joseph S. Hepburn, A.M., M.S., Secretary of the Section, delivered an address upon "Recent Progress in the Chemistry of the Sugars." The nomenclature of the sugars was explained and the reactions involved in Fischer's syntheses of monoses, glucosides and disaccharides were discussed. The behavior of the synthetic sugars toward yeasts, and the action of the inverting enzymes,—invertin, emulsin, maltase and lactase,—upon the glucosides and disaccharides were considered. Mention was made of the modes of separation of racemic compounds of the sugar group into their antipodes, and attention was given to the asymmetric syntheses which occur within that group. The lecture was illustrated with lantern slides, and with specimens of the sugars and their related compounds.

The paper was referred for publication. On motion of Dr. Harry F. Keller, a vote of thanks was tendered the speaker. The meeting then adjourned.

JOSEPH S. HEPBURN,
Secretary.

FRANKLIN INSTITUTE

MEMBERSHIP NOTES.

At the Stated Meeting of the Board of Managers, held Wednesday, June 8, the following gentlemen were elected to membership:

Resident.

JOSEPH REED COLLINGWOOD, 511 South Forty-first St., Philadelphia, Pa.

MATTHEW H. DEVEY, 2443 North Twenty-ninth St., Philadelphia, Pa.

Non-Resident.

FRANK HEPBURN, 157 West Forty-fourth St., New York City.

S. J. MACFARREN, 1403 New York Ave., Washington, D. C.

OSWALD WEIGEL, Königstrasse 1, Leipzig, Germany.

Change of Address.

CHARLES E. FOSTER, 908 G St., N. W., Washington, D. C.

ROBERT JOB, care Milton Hersey Company, Ltd., 171 St. James St., Montreal, Canada.

H. PEMBERTON, Jr., Adirondack Summer School, Saranac Lake, N. Y.

F. RODNEY PLEASONTON, 108 North Second St., Harrisburg, Pa.

OBITUARY.

C. J. Toerring died in Philadelphia, Pa., April 22. He was born in Skive, Denmark, September 18, 1870. After completing the public school course in Davenport, Iowa, he entered the University of Illinois at Urbana, transferring to Cornell University in his junior year and graduated in 1893.

For about a year he was engaged in the laboratory and engineering department of an arc lamp company in New York City, and later became associated with the Helios Electric Company, of Philadelphia.

In 1898 he organized the company which bears his name.

The arc lamps of his design are considered of distinctive merit. They were granted recognition at numerous expositions, including the gold medal at the Paris Exposition in 1900; highest award at the National Export Exposition, Philadelphia, 1899; also awards at Buffalo, N. Y., in 1901, and St. Louis in 1904. The Edward Longstreth medal of merit was awarded by the Franklin Institute in 1903. He was a strong advocate of inverted lighting, *i.e.*, indirect illumination, and his inverted enclosed arc lamp, which he designed some years ago, gained many converts to this method of lighting.

LIBRARY NOTES.

Purchases.

ARMSTRONG, E. F.—"Simple Carbohydrates and the Glucosides."
Century Dictionary and Cyclopædia, vols. 11–12, 1909 edition.
CUSHMAN, A. S., and H. A. GARDNER.—"Corosion and Preservation of Iron and Steel."
GODFREY, EDWARD.—"Concrete."
GODFREY, EDWARD.—"Godfrey's Tables."
HUBBARD, PRÉVOST.—"Dust Preventives and Road Binders."
JONES, H. C.—"Elements of Physical Chemistry," Ed. 4.
LAMB, HORACE.—"Dynamical Theory of Sound."
Marseille Congrés International des Application de Electricite, 3 vols.
"Meteorologischen Zeitschrift Namen und Sachregister," Bänden 1, xxv, 1884–1908.
RICHARDS, ROBERT H.—"Ore Dressing," vols. iii and iv and Index.
SCHAFFERS, V.—"Machine a Influence son Evolution, sa Theory."
STEINMETZ, C. P.—"General Lectures on Electrical Engineering."
STEINMETZ, C. P.—"Theory and Calculation of Transient Electric Phenomena and Oscillations."
STEWART, A. W.—"Recent Advances in Physical and Inorganic Chemistry."
WEINGREEN, J.—"Electric Power Plant Engineering."
WILSON, H. M.—"Irrigation Engineering," Ed. 6.

Gifts.

Inspector's Handbook of Reinforced Concrete, by Ballinger and Perrot.
Ontario Bureau of Industries, Report, Toronto, 1909.
Ontario Agricultural College, Report, Toronto, 1910.
Society of Naval Architects and Marine Engineers, Transactions, vol. 17 Washington (n.d.).
Connecticut Geological and Natural History Survey, vol. 2, Hartford, 1909.
"The Theory of Electrons," by H. A. Lorentz, New York, 1909.
Report on the Blackwell's Island Bridge, Pennsylvania Steel Co., Steelton, 1909.
Springfield, Mass., Water Commissioners, Report, 1909.
Nova Scotia Mines Department, Report, Halifax, 1910.
Newton, Mass., City Engineer, Report, 1909.
Hebrew Technical Institute, Report, 1909; Catalogue, 1910, New York (n.d.).
Georgia Geological Survey, Bulletin No. 23, Atlanta, 1910.
"Fields of Force," by Vilhelm Friman Koren Bjerknes, New York, 1906.
Philadelphia Board of Directors of City Trusts, Report, Philadelphia, 1910.

TRADE CATALOGUES.

American Car and Foundry Company, Catalogue B, New York, 1903; Catalogue D, New York (n.d.).
"How to Light Your Home by Electricity," The Electric Storage Battery Co., Philadelphia.

PUBLICATIONS RECEIVED.

The Standard Oil Company. By Elbert Hubbard, being a reprint from *The Fra* (Magazine). 24 pages, 12mo. East Aurora, N. Y. The Roycrofters 1910.

Das C. R. Gesetz und die Kabelschneeltelegraphie von Béla Gáti. Sonderabdruck aus "Electrotechnik und Maschinenbau," Zeitschrift des Elektrotechnischen Vereins. In Wien, Heft 37, 1909. 5 pages, illustrations, 4to. Vienna. n. d.

U. S. Department of the Interior. The Bureau of Science, Manila. The Mineral Resources of the Philippine Islands with a Statement of the Production of Commercial Mineral Products during the year 1908. Issued by Warren D. Smith, Ph.D., Chief of the Division of Geology and Mines, Bureau of Science. 49 pages, illustrations, plates, maps, 8vo. Manila, Bureau of Printing, 1909.

Canada Department of Mines. The Production of Asbestos in Canada during the calendar year 1907-8. By John McLeish, B.A., Chief of the Division of Mineral Resources and Statistics. 8 pages, 8vo. Ottawa, Government Printing Bureau, 1909.

Königliches Materialprüfungsamt der Technischen Hochschule zu Berlin. Bericht über die Tätigkeit des Amtes im Betriebsjahr 1908 (April, 1908, bis April, 1909). Sonderabdruck aus Mitteilungen aus dem Königlichen Materialprüfungsamt zu Gross-Lichterfelde West. 87 pages, 4to. Berlin, Julius Springer, n. d.

Le Revers de la Révolution. L'Insurrection en Russie, armée aux frais du Japon. 19 pages, 8vo. St. Petersburg, "Golos Pravdy," 1909.

Canada Department of Mines. The Production of Chromite in Canada during the Calendar Years 1907-8. By John McLeish, B.A., Chief of the Division of Mineral Resources and Statistics. 6 pages, 8vo. Ottawa, Government Printing Bureau, 1909.

International Institute of Agriculture at Rome. Letter written by David Lubin to Hon. George C. Perkins and Hon. Frank P. Flint relative to the International Institute of Agriculture at Rome. Read in the U. S. Senate by Mr. Perkins. 6 pages, 8vo. Washington, 1909.

Recherches sur la préparation électrolytique des composés du plomb. Par Carl Duvivier. 19 pages, 8vo. Malines, L. and A. Godenne, 1909.

La Définition et la Mesure industrielles de l'Accélération des Trains. Par C. O. Mailloux, avec notes de R. Legouëz et J. Blondin. Extraits de la Revue électrique du 30 Novembre et du 30 Décembre 1908. 11 pages, 4to. Paris, Gauthier-Villars, 1908.

Report of a Fire-, Load- and Water-Test made upon Reinforced-Cinder-Concrete Floor-Arches constructed by the Trussed Concrete Steel Company at the University Fire-Testing Station, New York City, Test conducted by Ira H. Woolson, E.M., Adjunct Professor of Civil Engineering, in co-operation with the City Building Bureaus. 28 pages, illustrations, 8vo. Paper, price 25 cents. New York, 1909.

International Arbitration and Peace. The Mission of America in the Politics of the World. In the House of Representatives. Extract from the Congressional Record. 16 pages, 8vo. Washington, 1909.

National Association of Cotton Manufacturers. Advance copies of papers to be read at the Annual meeting, No. 88, Boston, Mass., April 27 28, 1910. 16 pamphlets, illustrations, 8vo.

A New Theory on the Pacific Coast Climate. By Sereno E. Bishop. (Reprinted from Honolulu Chamber of Commerce Annual for 1909.) 7 pages, 8vo. Honolulu, Hawaii Promotion Committee, n. d.

Wissenschaftliche Abhandlung über das Theorem des Mathematikers Fermat $x^n + y^n = z^n$. Von O. Heck zu Selters in Oberhessen. 16 pages, 12mo. Büdingen, Büdinger Tageblatt, 1909.

Waterways—The Atlantic Coast Trunk-Line. Speech of Hon. J. Hampton Moore of Pennsylvania in the House of Representatives, Tuesday, July 27, 1909. 14 pages, 8vo. Washington, 1909.

U. S. House of Representatives, Committee on Agriculture. A report on "The Influence of Forests on Climate and on Floods," by Willis L. Moore, LL.D., Sc.D., Chief of the U. S. Weather Bureau. 38 pages, illustrations, maps, 8vo. Washington, Government Printing Office, 1910.

Canada Department of Mines. Preliminary Report on the Mineral Production of Canada During the Calendar Year 1909, prepared by John McLeish, B.A. 18 pages, 8vo. Ottawa, Government Printing Bureau, 1910.

Canada Department of Mines. Iron Ore Deposits of Vancouver and Texada Islands, British Columbia, by Einar Lindeman, M.E. 29 pages, maps, 8vo. Ottawa, Government Printing Bureau, 1910.

Canada Department of Mines. Joint Report on the Bituminous, or Oil-Shales of New Brunswick and Nova Scotia; also on the Oil-Shale Industry of Scotland. Pt. I, Economics; Pt. II, Geology. By R. W. Ellis, LL.D., F.R.S.C. 75 pages, illustrations, plates, 8vo. Ottawa, Government Printing Bureau, 1910.

Designing Data for the Use of Expanded Metal and Expanded Metal Lath as Manufactured by the Northwestern Expanded Metal Company. 70 pages, illustrations, 16mo. Chicago, Company, 1910.

Report of the Commissioner of Education for the Year Ended June 30, 1909. Volumes i and ii, 1373 pages, 8vo. Washington, Government Printing Office, 1909–10.

U. S. Department of Commerce and Labor, Coast and Geodetic Survey. Results of Observations made at the Coast and Geodetic Survey Magnetic Observatory at Sitka, Alaska, 1905–1906, by Daniel L. Hazard. 115 pages, illustrations, 4to. Washington, Government Printing Office, 1910.

Argentine Republic. Centenary of the Revolution of May 1810. Argentine Scientific Society. International American Scientific Congress to be held in Buenos Aires from the 10th to the 25th July 1910. Bulletin No. 1. 43 pages, 8vo. Buenos Aires (n.d.),

American Telephone and Telegraph Company. Annual Report of the Directors to the Stockholders for the Year Ending December 31, 1909. 40 pages, 8vo. Boston, Ellis Co., 1910.

University of Kansas, Bulletin, vol. ii, No. 1. Engineering Bulletin No. 1. A Ballistic Electrodynamometer Method of Measuring Hysteresis Loss in Iron, by Martin E. Rice and Burton McCollum. Voltage Regulation of Alternators, by Burton McCollum. 23 pages, illustrations. Lawrence, Kansas, University, November, 1909.

Cleveland Engineering Society, Journal. Volume ii, Nos. 2 and 3, 8vo. Cleveland, Ohio, Society, December 1909, March 1910.

The Spectroscopic Camera. Notes on the Use of the Spectroscopic Camera, designed by Alex. A. K. Tallent, author of Trichromatic Section of "A Handbook of Photography in Colors." 20 pages, illustrations, plates, oblong 32mo. London, A. W. Penrose & Co., Ltd. (n.d.).

Special Libraries. Volume i, No. 2. 8 pages, 8vo. New York, Special Libraries Association, February, 1910.

Michigan State Board of Health. Thirty-sixth Annual Report for the Fiscal Year Ending June 30, 1908. 222 pages, 8vo. Lansing, State Printers, 1909.

Les Mathématiques en Portugal. Deuxième Défense, Travaux de Antonio Cabreira. 118 pages, 8vo. Lisbonne, L'Auteur, 1910.

United States Geological Survey. Mineral Resources of the United States. Calendar year 1908. Part I, Metallic Products; Part II, Non-metallic Products. 2 vols, 8vo. Washington, Government Printing Office, 1909.

Ontario Bureau of Mines. General Index to the Reports of the Bureau. Volumes i to xvi (1891–1907). Compiled by Frank J. Nicolas. 466 pages, 8vo. Toronto, King's Printer, 1909.

National Association of Cotton Manufacturers, Transactions No. 86. Annual Meeting held at Boston April 29–30, 1909. 556 pages, illustrations, 8vo. Boston, Association, 1909.

University of Illinois Bulletin, vol. vi, No. 3. The Mineral Content of Illinois Waters, by Edward Bartow, J. A. Udden, S. W. Parr, and George T. Palmer. Water Survey Series No. 4. 192 pages, 8vo. Urbana, University, September 15, 1908.

Armour Institute of Technology, Bulletin (new series), vol. iii, No. 1. General Information number. 174 pages, 8vo. Chicago, Institute, May, 1909.

Ontario Bureau of Mines. Eighteenth Annual Report, 1909. Volume xviii, Part I. 311 pages, illustrations, maps, 8vo. Toronto, King's Printer, 1909.

Dactiloscopia Argentina su historia é influencia en la legislacion por Luis Reyna Almandos. Contribucion al IV Congreso Cientifico Latino Americano (1er Pan-Americano). 271 pages, plates, tables, 8vo. LaPlata, Joaquin Sesé, 1909.

U. S. Census Bureau. Forest Products, No. 2. Lumber, Lath, and Shingles, 1908. 57 pages, 8vo. Forest Products, No. 5: Veneers, 1908. Forest Products, No. 6: Tight Cooperage Stock, 1908. Forest Products, No. 7: Wood Distillation, 1908. Forest Products, No. 10: Forest Products of the United States. 5 pamphlets, 8vo. Compiled in co-operation with the Department of Agriculture. Washington, Government Printing Office, 1909.

Canada Department of Mines. Report on the Iron Ore Deposits Along the Ottawa (Quebec side) and Gatineau Rivers, by Fritz Cirkel. 147 pages, illustrations, plates, maps, 8vo. Ottawa, Government Printing Bureau, 1909.

Against the Capital of K. Marx the Theory of the Technical Rents, by Engineer A. Trofimoff (in Russian). 292 pages, plates, 8vo. Tula, Russia, 1910.

Metal Industry Directory 1910. 8 pages, 8vo. New York, Metal Industry Publishing Co. (n.d.).

U. S. Coast and Geodetic Survey. Results of Magnetic Observations Made by the Coast and Geodetic Survey Between July 1, 1908, and June 30, 1909, by R. L. Faris, Inspector of Magnetic Work. Appendix No. 3. Report for 1909. 77–149 pages, 4to. Washington, Government Printing Office, 1910.

U. S. Coast and Geodetic Survey. Distribution of the Magnetic Declination in Alaska and Adjacent Regions, for 1910, by R. L. Faris, Inspector of Magnetic Work. Appendix No. 4. Report for 1909. 151–179 pages, maps, 4to. Washington, Government Printing Office, 1910.

U. S. Geological Survey. Mineral Products of the United States, Calendar years 1899 to 1908. Edward W. Parker, Statistician in charge of Mineral Resources. Sheet 24 x 32 inches. Washington, 1909.

Oxhydric Process for the Cutting and Welding of Metals. 23 pages, illustrations, 8vo. Milwaukee, American Oxhydric Co., January, 1910.

Canada Department of Mines. Production of Natural Gas and Petroleum in Canada During the Calendar Years 1907 and 1908. 15 pages, 8vo. Ottawa, Government Printing Bureau, 1909.

Canada. Department of Mines. The Production of Coal, Coke, and Peat in Canada During the Calendar Years 1907 and 1908. 34 pages, 8vo. Ottawa, Government Printing Bureau, 1909.

Canada. Department of Mines. The Production of Iron and Steel in Canada During the Calendar Years 1907 and 1908, by John McLeish, B.A., Chief of the Division of Mineral Resources and Statistics. Ottawa, Government Printing Bureau, 1909.

U. S. Bureau of Steam Engineering. Annual Report of the Chief of the Bureau to the Secretary of the Navy, for the Fiscal Year 1909. 70 pages, 8vo. Washington, Government Printing Office, 1909.

The Truth About Mexico, by E. S. Smith. 8 pages, portrait, 8vo. Reprinted from the Bankers' Magazine, November, 1909.

Industrial Peace and Industrial Efficiency. Sir Christopher Furness's Co-partnership Scheme. An account of "The Treaty of the Hartlepools." 30 pages, 8vo. New York, American Anti-Boycott Association (n.d.).

Royal Institution of Great Britain. Tantalum and its Industrial Applications, by Alexander Siemens. 8 pages, 8vo.

———— The World of Life: as Visualized and Interpreted by Darwinism, by Alfred Russel Wallace. 7 pages, 8vo.

———— The Electrical Properties of Flame, by Prof. Harold Albert Wilson. 4 pages, 8vo.

———— Experiments at High Temperatures and Pressures, by Richard Threfall. 20 pages, illustrations, 8vo.

———— Solar Vortices and Magnetic Fields, by Prof. George E. Hale. 16 pages, plates, 8vo.

———— Researches in Radiotelegraphy, by Prof. J. A. Fleming. 32 pages, 8vo. London, Institution, 1909.

U. S. Department of Agriculture. Forest Service Circular No. 171: "The Forests of the United States—Their Use," by Overton W. Price, Associate Forester, and R. S. Kellogg and W. T. Cox, Assistant Forester. 25 pages, 8vo. Forest Service Circular No. 172: "Method of Increasing Forest Productivity," by E. E. Carter, Assistant Forester. 16 pages, 8vo. Washington, Government Printing Office, 1909.

Biographical Sketch of L. A. Bauer, reprinted from The National Cyclopædia of American Biography. 8 pages, portrait, 16mo. New York, James T. White & Co., 1909.

Recent Observations in Atmospheric Electricity, by P. H. Dike. 197–209 pages, 8vo. Reprinted from the American Journal of Science, vol. xxvii, March, 1909.

Carnegie Institution, Department of Terrestrial Magnetism. Annual Report of the Director, 1909. 194–202 pages, plates, 8vo. Reprinted from Year-Book No. 8.

An Experimental Investigation of Dip-needle Corrections, by P. H. Dike. 137–146 pages, illustrations, 8vo. Reprinted from Terrestrial Magnetism and Atmospheric Electricity for September, 1909.

United States Magnetic Tables and Magnetic Charts for 1905, by L. A. Bauer. 41–53 pages, 8vo. Reprinted from Terrestrial Magnetism and Atmospheric Electricity for March, 1909.

Zoölogical Bulletin of the Division of Zoölogy of the Pennsylvania Department of Agriculture. Vol. vii, Nos. 3 to 10, 8 pamphlets, 8vo. H. A. Surface, M.S., Economic Zoölogist, Editor. Harrisburg, State Printer, August, 1909, to March, 1910.

Manchester Steam Users Association. Memorandum by Chief Engineer for the Year 1908. 65 pages, illustrations, 8vo. Manchester, Taylor, Garnett, Evans & Co., 1909.

The Periodic Law and the Hydrogen Spectrum. By W. F. Kemble and C. R. Underhill. 16 pages, plates, 8vo. New York, D. Van Nostrand Co., 1909. Paper, price 50 cents.

CURRENT TOPICS

Vibrations of an Incandescent Filament. (*Sci. Americ.*, xii, 17.)—By microphotographic methods, the vibrations in an incandescent filament, due to the expansion and contraction caused by the passage of an alternate current, have been recorded. An arc lamp was used as the source of light for photographic purposes, and when the arc was fed from the same alternator as the incandescent filament, the vibrations were seen from the plate to synchronize with the rise and fall of the alternating pressure. With a 100 candle-power osram lamp, supplied with alternate current at 50 alternations, a slight humming noise was perceptible even at a distance of three yards. The experimenter considers that this may be a cause contributing to the shorter life of a metallic filament on alternate current.

Drawn Tungsten Filaments. (*Sci. Americ.*, xii, 17.)—Tungsten filaments are commonly made by mixing the metal in a paste that is then extruded in the form of a filament, after which the paste is expelled and the particles of metal are welded together by an electric current. This complicated method of forming the filaments is due to the fact that tungsten is not sufficiently ductile to be drawn out into fine filaments. An English concern has just discovered a method of producing drawn filaments of tungsten, and the General Electric Company has also just announced the discovery of a method by which tungsten may be rendered sufficiently ductile to permit of its being drawn into fine wires. The drawn tungsten filament is stronger than the filament made by the " sintering " process.

Synthetic Rubber. (*Sci. Americ.*, xii, 17.)—Prof. KARL HARRIES, of the University of Kiel, is said to have produced a synthetic rubber. The actual details of the process are not yet available. Similar attempts have been made repeatedly, but with no commercial success. The most that can be said for them is that they indicate the possibility of producing a synthetic rubber from turpentine at some future time.

Synthesis of Methane. BONE and COWARD. (*La Nature*, No. 1925.)—Messrs. Bone and Coward have studied the conditions of the direct combination of carbon and hydrogen and have realized the synthesis of methane. They state they have formed large quantities of this gas when less than 0.1 Gm. of the carbon from sugar was heated in a current of pure and dry hydrogen between 1100° and

1200° C., in an apparatus specially constructed to attain these temperatures. The carbon used was purified by prolonged heating in dry chlorine at a temperature from 700° to 1100° C. In two different experiments, they obtained 137 c.c. and 125.5 c.c. of methane, measured at 0°, and 760 mg., from 0.095 Gm. and 0.092 Gm. of carbon respectively, which is a yield of about 73 per cent. of the theoretical proportion; the rest of the methane was lost either through oxidation or by a decomposition, unavoidable on account of the intense heat of the walls of the porcelain tube in which the carbon was heated. The observers have thus convincingly confirmed the synthesis of methane from its elements, carbon and hydrogen, a synthesis which has often been disputed, and which in any case has only been successful with very small quantities of the substances.

Sterilization of Water by the Ultra-Violet Rays. (*La Nature*, No. 1925.)—Messrs. V. HENRY, A. HELBRONNER, and CH. VON RECKLINGHAUSEN have designed an apparatus which practically realizes the sterilization of running water by means of the ultra-violet rays. This apparatus sterilizes 125 cubic metres per hour, which is sufficient to supply a town of 20,000 inhabitants. The cost of the electricity required to effect the sterilization is 36 watts per hour per cubic metre. The apparatus has been tested by water previously contaminated with various microbes. The proof was quite decisive as the sterilization was complete. But the water must be previously clarified, for matter in suspension prevents the passage of the ultra-violet rays. The water flows through a series of tubes in which are placed lamps emitting ultra-violet rays. After passing before the first lamp the number of microbes was about 5250 per cubic centimetre, after passing the second lamp analysis showed no bacilli.

Preservation of Eggs in Cold Storage. (*Sci. Americ.*, xii, 17.)—A new system of treating eggs so as to prevent them from growing stale when in cold storage has been discovered in Rochester. This consists in subjecting the eggs to an electrical current. The theory is that eggs when placed in storage are alive and are gradually frozen to death, whereas if the life is destroyed by an electrical current before they are placed in storage they do not taste stale, even when kept on ice for a long period of time.

Electro-Metallurgy of Zinc. V. ENGELHARDT and M. HUTH. (*Metallurgie*, 1910, vii.)—The electrolytic refining of zinc is unprofitable. Copper refining yields valuable by-products in the noble metals. The Friedrich's-hütte factory tried to refine electrolytically the residue from the zinc-desilveration process, but it proved too expensive. Neither was Hopfner's electrolysis of zinc chloride economical. There remains the sulphate electrolysis. The ore is roasted, extracted with sulphuric acid, the solution purified and

then electrolyzed. Good zinc is only obtained from pure solutions. When hydrogen is evolved spongy zinc forms and is redissolved in the free acid. The chief trouble is the insoluble anode. Carbon is destroyed. Anodes of manganese peroxide are good.

An Electric-Lighting Plant Making Ice. (*Sci. Americ.*, xii, 17.)—An electric-lighting plant in Nebraska manufactures ice as a by-product. The exhaust steam of the plant, instead of going to waste, is utilized in the ammonia absorption process of ice manufacture, and also for distilling water from which the ice is made. The venture has proved very profitable for the lighting company and might be utilized by other plants similarly situated.

Reaction of Nascent Hydrogen. A. C. VOURNASOS. (*Comptes rendus*, 1910, 150.)—Nascent hydrogen liberated on heating dry sodium formate reacts with several elements which do not combine directly with free hydrogen.

Phosphorus.—When sodium formate melted at 200° C. is subjected (after the air has been displaced by hydrogen) to phosphorus vapors obtained by heating phosphorus to 400°–450° C., phosphoretted hydrogen, mixed with phosphorus vapors, is readily formed. This gas is also formed when a mixture of 1 part of red phosphorus and 5 parts of sodium formate, or preferably an equimolecular mixture of sodium formate and hydroxide, is heated in a tubulated retort, after expelling the air by hydrogen, to 400° C.; or when a mixture of sodium formate and neutral sodium phosphite (or anhydrous disodium phosphate) is similarly heated.

Sulphur.—Hydrogen sulphide is obtained in a similar manner by heating 1 part of flowers of sulphur with 4 parts of an equimolecular mixture of sodium formate and hydroxide to 400° C., as above. Sodium sulphite is also reduced with production of hydrogen sulphide. The sulphides of mercury, lead, and tin similarly treated yield their respective metals and hydrogen sulphide. *Arsenic* and sodium arsenite readily yield arseniuretted hydrogen. Sodium antimonite yields a little stibine. Silicon does not react, but its chloride and sulphide give a little hydrogen silicide. Nitrides yield ammonia; cyanides, hydrocyanic acid; alkali carbides yield acetylene, etc.

The Induction Generator. T. SPOONER and A. J. BARNES. (*Electrical World*, 1910, 55.)—The operation of induction generators in parallel with synchronous machines is discussed. An induction generator is simply an induction motor driven at a speed above synchronism. The voltage and frequency are governed respectively by the field strength and the speed of the synchronous apparatus. The first point investigated was the effect of short-circuit on the system. Oscillograph records are shown, illustrating what happens when the generator is short-circuited, when supplying energy to a

non-inductive load. Theory shows that a short-circuit is equivalent to a withdrawal of the exciting current, and hence the generator ought to produce no energy. This was found to be the case. Corresponding oscillograms are shown for the case when the generator was working on a capacity-load previous to the short-circuit. It is proved that induction generators have the following advantages: (1) They do not require the protection of cut-outs, as short-circuits do not harm them. (2) No large mechanical stresses are produced during short-circuit. (3) As soon as a short-circuit is removed, the generators work normally.

Chemical Reactions in Gases at High Pressures. E. BRINER and A. WROCZYNSKI. (*Comptes rendus*, 1909, 149.)—The authors find that when a mixture of 3 volumes NO and 1 volume HCl is subjected to a pressure of 300 atmospheres at the ordinary temperature, nitrosyl chloride is gradually formed. Further, under the same conditions, nitric oxide yields continually increasing quantities of nitrous oxide, decomposing according to the equation $3NO = N_2O_3 + N$. This decomposition evidently precedes the formation of nitrosyl chloride from nitric oxide and hydrogen chloride, the second stage being represented thus:

$$N_2O_3 + 2HCl = 2NOCl + H_2O.$$

The Mallet Locomotive. (From *Scientific American*, cii, 17.)—The Mallet articulated compound locomotive continues to grow in favor; the reports from this type of locomotive in service are generally favorable. The N. Y. Central system has recently put a Mallet compound in service on the Boston and Albany line. The present class of heavy freight engine on that road has a maximum tractive power of 26 tons, whereas the Mallet, when working compound has 33 tons, when working simply 40 tons tractive power. The success of the type in freight service is undisputed. The future will tell what results it will give in fast passenger service.

Ozone in the Flame. W. MANCHOT. (*Ber.*, xlii.)—By the use of the reaction between Ag and O_3 the author demonstrates the presence of this gas in hot flames. The quantity is greatest in the hottest portions of the flame, which agrees with Nernst's calculations that the equilibrium between O_2 and O_3 favors the latter at high temperatures. The ozone can be detected in any very hot flame such as the oxyhydrogen or even the ordinary gas blast. But cooler flames, like CO burning in air, show little ozone, though CO burning in oxygen shows considerable, due to the higher temperature. The oxidation of Ag by O_3 gives a different appearance from that caused by oxides of nitrogen or H_2O_2, and the reaction is therefore specific for O_3. H_2O_2 can be detected in the flame by playing an oxyhydrogen blast directly against the surface of a concentrated Titanium solution, the yellow color appearing in a half minute.

Changing the Color of the Diamond. PAUL SACERDOTE. (*Comptes rendus,* 149.)—The author's results in a number of experiments on colorless and yellowish diamonds are: (1) The X-rays do not change the color of the diamond perceptibly. (2) The cathode rays of a vacuum tube changed the appearance of the diamond placed within the tube from colorless or pale yellow to the color of "Madeira wine" and finally to a more or less pronounced brown, dependent on the length of exposure. (3) This color is permanent and unaffected by direct sunlight. (4) A temperature of 300° to 400° C. removes this coloration.

Physiological Effects Produced by an Alternating Magnetic Field. S. P. THOMPSON. (*Comptes rendus,* cl, 16.)—Up to the present time it has been admitted that magnetism produces no physiological effect; it has been positively stated that if one's head is placed between the poles of a powerful electro-magnet, one feels no effect. However, by operating in an alternating field of sufficient force, a positive action is obtained, which was perceived by all who underwent the experiment. The field was produced by a coil of 32 turns of a copper wire, large enough to carry about 180 ampères; the coil was 8 inches long and 9 inches in diameter. The rate of the current was 50 per second. The maximum value of the field was 1400 units C.G.S. at the centre. On placing the head in this coil an observer perceived, in the dark or by closing the eyes, a weak and fluctuating light, either colorless or slightly bluish. The period of fluctuation is badly defined; and is more brilliant at the periphery than at the centre. Even in full daylight, with the eyes open, there is a sensation of a luminous fluctuation. These effects increase or diminish with the intensity of the electric current. The senses of hearing and smell are unaffected. Taste is affected in the same way as sight.

Agitation by Air and Steam. (*Power,* xxxii, 19.)—In some metallurgical operations steam is admitted to large tanks to produce agitation. In certain cases the consumption of steam is enormous and the quantity of steam can be greatly reduced and the agitation much increased by allowing the steam to carry in air through an injector. First turn on the steam, then open the valve of the injector until the desired amount of air is obtained.

Controlling a Ship's Water-tight Bulkhead Doors. (*Engineering,* lxxxix, 2313.)—The Stone-Lloyd system of controlling such doors by hydraulic power is becoming widely employed, owing chiefly to the absence of expense for upkeep and repair. This system is to be adopted in the large trans-Atlantic steamer *La France* and in the new Japanese dreadnought now building at Yokosuka. This vessel has 22 doors. The Japanese authorities accept the contention of the owners of the Stone-Lloyd system that hydraulic

power alone can be relied upon to work satisfactorily in the damp and dirt of stokeholds, that steam is dangerous, and that electricity is liable to fail at the critical moment, and dangerous where there is a possibility of fire-damp.

Hardening of Carbon and Low-Tungsten Tool-Steels. S. N. BRAYSHAW. (*Engineering*, lxxxix, 2313.)—Such steel has a long range of quite 120° C. (216° F.) within which it may be hardened to show a good fracture. The lower end of this range is very sharply defined but the highest temperature allowable is difficult to determine, and there is little evidence of bad work (so far as the appearance of the fracture is concerned) until the temperature of the hardening point has been exceeded by 150° C. (270° F.). In the light of the experiments recorded it is not to be supposed that most of the articles hardened by judging the temperature by sight alone, reach anything like their maximum efficiency, for slight variations in the heat treatment previous to quenching have a profound effect upon the condition of the steel, and the previous treatment by annealing or otherwise may powerfully influence the final result. It has been demonstrated that so far as bending tests are concerned it is easy to harden so as to produce a good bar, but the production of the best bar necessitates a degree of accuracy beyond what can be determined by sight alone; and the difference between good bars and the best bars is very great.

For some years the efforts of steel makers have been mainly directed towards the discovery of new alloys, and splendid success has been achieved. The time will come when all the factors in the hardening of tool-steel will be controlled with accuracy within predetermined limits, and any failure will be investigated, and the blame apportioned with as much certainty as if a mistake had been made in the machine shop.

The Weathering of Coal. S. W. PARR and W. F. WHEELER. (*Eng. Record*, 61, 18.)—Coal of the type found in Illinois and neighboring states is not affected seriously during storage when only the changes in weight and losses in heating powers are considered. The changes in weight may be either gains or losses of probably never over 2 per cent. in a period of one year. The heating value decreases most rapidly during the first week after mining, and continues to decrease more and more slowly for an indefinite time. In the coals tested 1 per cent. is about the average loss for the first week, and 3 to 3½ per cent. would cover the losses for a year, although sometimes they reach 5 per cent. The losses due to disintegration and to spontaneous ignition seem to be of far greater importance, though they cannot be expressed in figures for comparison. The storage of coal of a size larger than is to be used would overcome part of this loss. The larger sizes of coal are also much less liable to take fire spontaneously. Storage under water

will largely prevent disintegration, and will absolutely prevent fire losses. Apart from this there seems to be very little in favor of any particular method of storing.

Passage of Bacteria Through Sand-Filters. RUDOLPH HERING. (*Eng. Record,* lxi, 18.)—The conclusion arrived at is that properly devised and operated filters will safely remove pathogenic bacteria, when the raw water is *not much* polluted. There appears to be sufficient evidence, however, that with a sufficient quantity of nutriment dissolved in the water, pathogenic bacteria not only *pass through* filters, but that their number may *actually increase* within them. With these facts in mind double filtration was proposed as a safeguard, and has been practised in Altona and Bremen in Germany for a number of years.

Fortunately we have now a remedy against the danger of escaping pathogenic bacteria by their direct destruction with calcium and sodium hypochlorite, which can be economically applied in connection with the filtration of water supplies, and also for sewage purification after the suspended organic matter has been substantially removed by filters or otherwise.

Iron Ore Deposits of Australia. J. BOWIE WILSON. (*Eng. and Min. Journal.*)—One of these is on Iron Island, about 10 miles off the coast of Queensland. In the past three years about 90,000 tons of ore have been shipped. A sample showed iron 64–72 per cent., silica 2.51 per cent., alumina 2.95 per cent., lime 2.85 per cent., magnesia 1.07 per cent., and phosphorus 0.065 per cent. The other is on Koolan Island, off the west coast. The iron ore is on the south side; it is anhydrous and has a black metallic lustre and contains iron 66.48 per cent., silica 4.16 per cent., sulphur 0.072 per cent., phosphorus 0.064 per cent.

The Briey Iron Ore Deposits. (*Iron Age,* lxxxv, 15.)—These deposits in Briey, France, are the continuation of those in German Lorraine and Luxemburg. The whole deposit covers about 328 square miles, of which about 150 are in German Lorraine, the same in France, and the remainder in Luxemburg. It is estimated that the Lorraine-Luxemburg deposits contain 2700 million tons of ore. French Lorraine contains about 1300 million tons. Mining in the Briey basin is at a maximum depth of about 900 to 1000 feet. It is probable that at least a dozen German companies have bought or leased ore properties in this region.

Fluxes from the Viewpoint of the Metallurgist. L. J. KROM. (*Met. Ind.,* viii, 5.)—*Sal ammoniac,* or ammonium chloride, is particularly well adapted as a flux for zinc and aluminum. *Zinc chloride* is good for aluminum and its alloys, and does not affect the crucible. *Borax,* or sodium biborate, is good for easily oxidizable metals such as nickel, zinc, and copper; it attacks the crucible only to a small extent. *Calcium fluoride,* or fluorspar, alone or with

an equal quantity of lime, is useful for fluxing nickel or German silver. This strongly attacks the crucible. *Potassium cyanide* is an excellent flux for producing sound castings of copper, but is destructive to the crucible and is expensive and poisonous. *Potassium ferrocyanide* is well adapted for copper casting, but is likely to introduce some iron into the metal, so should only be used at the last minute before pouring. It is less expensive and not so poisonous as the cyanide. *Sodium carbonate* is a good flux for metal bearing material, but lime and fluorspar are better. *Magnesium sulphate,* or plaster of Paris, is used for the recovery of metals from sweepings and waste materials. *Potassium nitrate,* or saltpeter, is used extensively in the manufacture of German silver. It attacks the crucible rapidly.. Its best application is as a flux for purifying gold and silver, by oxidation. *Glass, mercury bichloride,* and *potassium bisulphate* are also used as fluxes.

A New Process of Galvanizing. (*The Metal Ind.*, viii, 3.)—A new process resembling sherardizing has been patented (U. S. Pat. No. 928,398). The iron or steel to be galvanized is coated with a paste composed of

Zinc flue dust	88 parts,
Lampblack	2 parts,
Clay	10 parts.

The ingredients are mixed with water and applied to the cleaned iron or steel surface. The whole is placed in a furnace and heated to a temperature of from 600° F. to 1000° F. for a period varying from one-half to four hours.

Permissible Explosives as Used in Coal-Mines. J. J. RUTLEDGE. (*Eng. and Min. Jour.*, 1910, lxxxix.)—Owing to numerous disastrous explosions in coal-mines in the United States believed to be due to the use of black blasting powder, the manufacture of permissible explosives has rapidly increased of late. These explosions, and the work of the Pittsburg Testing Station, have greatly extended the use of permissible explosives in the mining districts. There are three varieties of permissible explosives: the ammonium nitrate class; the nitro-glycerin class; and the hydrated class. These explosives are usually fired by electric detonators. One of their advantages is that they can be used in wet or damp holes. Another advantage is the absence of smoke, when properly fired; the miners are able to return to the place in about 30 seconds after the shot, without discomfort from the fumes. The objections to their use are: (1) they freeze at a rather high temperature; (2) they cost more per ton of coal produced than black powder; (3) some of them deteriorate rapidly on exposure to the atmosphere.

PRESS OF
J. B. LIPPINCOTT COMPANY
PHILADELPHIA